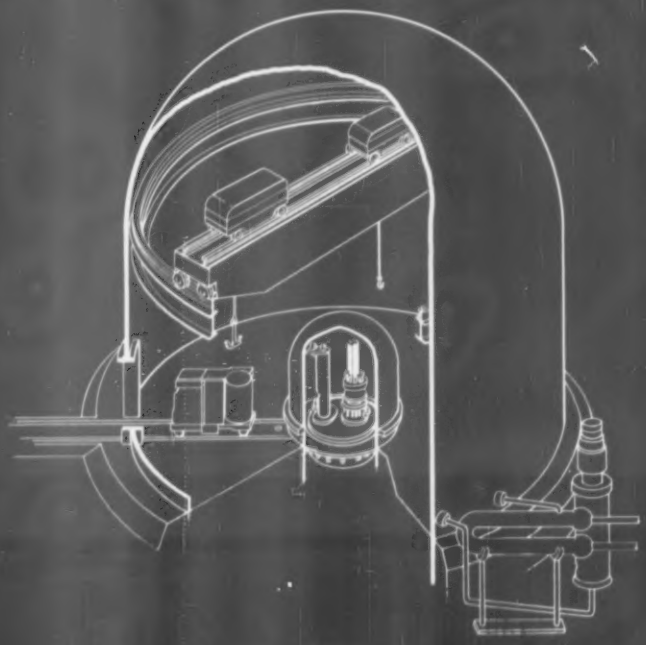
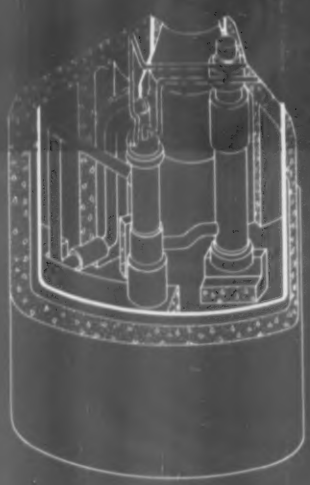
April 1957

A McGraw-Hill Publication • Seventy Five Cents

NUCLEONICS

ATOMIC POWER • NUCLEAR ENGINEERING • APPLIED RADIATION



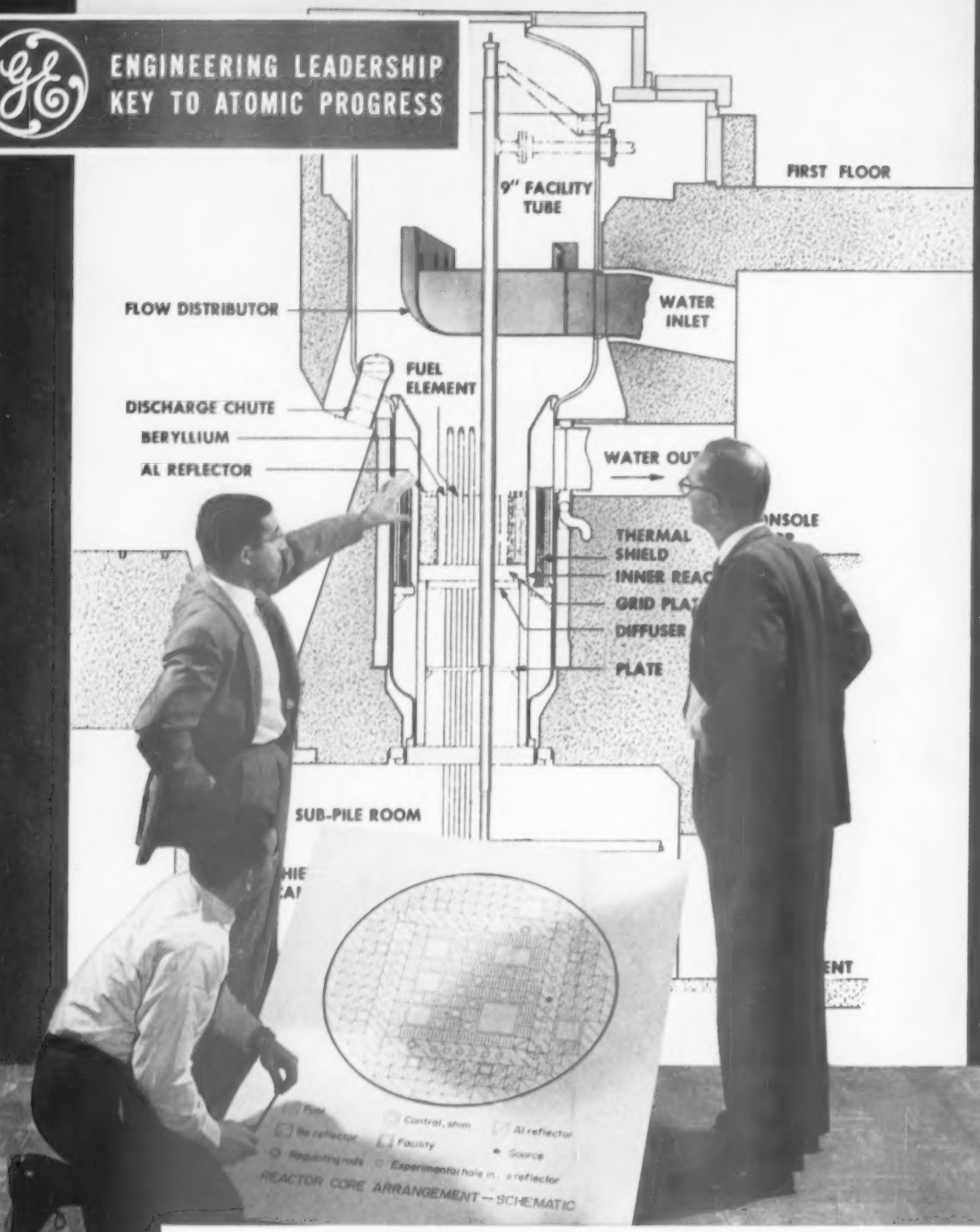


NUCLEONICS Reviews (p. 61)

Problems, Prospects for Fast Breeder Power Reactors as . . .

. . . First Central-Station Breeder Rises at Lagoona Beach page 68

ENGINEERING LEADERSHIP
KEY TO ATOMIC PROGRESS



General Electric engineers design 175,000-kw Engineering Test Reactor

A test reactor with extremely high flux, coupled with in-core testing facilities, presents heat transfer, physics and mechanical problems of a new magnitude. In designing the Engineering Test Reactor, General Electric engineers provided solutions to these difficult problems.

This reactor was designed by General Electric for Kaiser Engineers, prime contractor to the AEC, and will be placed in operation at the National Reactor Testing Station, Idaho.

The accomplishment of this design is another example of General Electric engineering leadership in the field of atomic energy. Atomic Power Equipment Department, General Electric Company, San Jose, California. 1964-4

Progress Is Our Most Important Product

GENERAL ELECTRIC

NUCLEONICS

ATOMIC POWER
NUCLEAR ENGINEERING
APPLIED RADIATION

VOLUME 15 NUMBER 4

H. W. Mateer, Publisher

Jerome D. Luntz, Editor

Daniel I. Cooper, Managing Editor
Thomas L. Cramer, Associate Editor
John E. Kenton, News Editor
R. Hobart Ellis, Jr., Assistant Editor
Harold L. Davis, Assistant Editor
Jesse S. Cook, III, Assistant Editor
Robert K. Otterbourg, Assistant Editor
Nancy Purves Case, Production Editor
Carol Williamson, Editorial Assistant
Patricia Simons, Editorial Assistant
Harry Phillips, Art Director
Roy Thompsen, Assistant Art Director
G. B. Bryant, Jr., Chief Washington Bureau
Craig Richter, Washington Office

John Wilhelm, Chief World News Staff

London—W. J. Coughlin, John Tunstall
Paris—Robert E. Farrell
Bonn—Morrie Helitzer
Tokyo—Dan Kurzman
Rio de Janeiro—Peter Weaver
Mexico City—Jack Kearney
Melbourne—Alicja Grobtuch
Beirut—O. M. Marashian
Brussels—A. P. L. Gordon
Bombay—Sharakh Sabavala
Copenhagen—Else Balslev
Geneva—Ernest Hediger
Johannesburg—G. M. Thain
Rome—Diego Straniero
Stockholm—George Williamson
Vienna—F. H. Baer

Keith Henney, Consulting Editor

●

James Girdwood,
Advertising Sales Manager

R. S. Quint, Assistant Advertising Sales Manager, Buyers' Guide Manager
Frederic Stewart, Promotion Manager
Frank H. Ward, Business Manager
Thomas Vought, Research
Wallace B. Blood, Market Consultant
Philip H. Hubbard, Jr., New York
Philip H. Hubbard, Jr., New England
James T. Hauptli, Philadelphia
B. Winner, W. Luce, Chicago
Warren H. Gardner, Cleveland
T. H. Carmody, R. C. Alcorn, San Francisco
Carl W. Dysinger, Los Angeles
M. Miller, Atlanta
G. L. Jones, D. Billian, Dallas
Herbert Lagler, London

CONTENTS APRIL 1957

A Special Report:

Fast Breeders Are Essential to Future Atomic Power 61
Fast-Breeder Power Reactors—Their Problems and Prospects 62
AEC's Fast-Reactor Program 67
The Enrico Fermi Reactor 68

Feature Articles

Pressurized Water Test Loop at MTR — EMIL L. MARTINEC 73
Is 'Conventional' Component Supply Delaying Nuclear Progress? 78
Gamma-Ray Dose and Heating from Spent MTR Fuel Elements — W. E. FRANCIS and L. L. MARSDEN 80
Data Sheet No. 19—Radiation from Neutron-Activated Slabs and Cylinders — W. B. LEWIS 84
Counting Thousands of Samples in 12 Hours—Automatically — KENNETH E. RELF 86

Cross Sections

Separated Channels Improve Liquid Scintillation Counting — MONTE BLAU 90
Temperature Dependence of Photomultiplier Gain — FRANK E. KINARD 92
Cerenkov-Photovoltaic Monitor for High-Intensity Radiation — C. C. THOMAS, Jr., K. H. SUN, and E. A. MARUSICH 98
Improved Molybdenum Separation Procedure — E. M. SCADDEN 102

Nuclear Engineering

Godiva Wrecked at Los Alamos 104
Air-Drying System for EBWR Turbine Seals — EDWARD L. YOUNG 105
Diphenyl as a Thermodynamic Fluid — D. C. PURDY 109

Applied Radiation

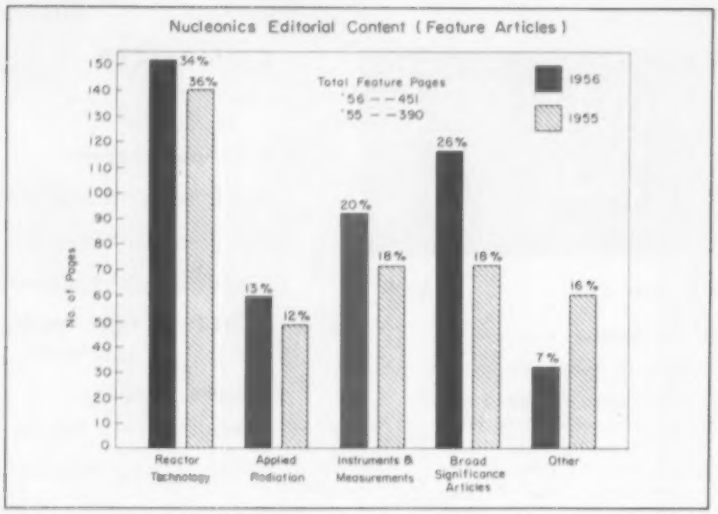
Gamma Facility for Use at High Temperatures — E. L. COLICHMAN, P. J. MALLON, and A. A. JARRETT 115

Departments

ROUNDUP	17	PRODUCTS AND MATERIALS	128
APPLIED RADIATION	114	NUCLEAR CAMPUS	132
BOOKS	120	NEWSMAKERS	133
LETTERS	124	NUCLEAR CALENDAR	135

More about NUCLEONICS on next page ▶

About NUCLEONICS



How to choose. We on NUCLEONICS can remember the barren days of yesteryear when we didn't know from one month to the next what might be coming along to fill out the following month's issue. To coin a phrase, "them days are gone forever." Now the problem is how to pick and choose from the vast fare available, how to use the allotted editorial page budget in the best fashion possible, and how to put the available editorial staff manpower to the most efficient use.

We can easily fill the pages of each issue with articles that come flowing into us, both solicited and unsolicited. But then, there are always the so-called spot-news developments, matters of interest to our readers that suddenly break into the news, both technical and nontechnical. This usually pushes other, less pressing articles off to later issues.

Take this April issue as an example. Three feature articles are based on information that became publicly available while the issue was being planned. Although we try to fill as much of each issue of NUCLEONICS with material that is exclusive to us, we won't hesitate to publish nonexclusive information if we feel it will be of considerable interest to our readers and/or we can bring some special treatment to it.

The status report on fast breeder power reactors (p. 62) and the description of the design of the Power Reactor Development Company breeder (p. 68) came out of the testimony presented at the hearings now going on on the PRDC reactor. Although the hearings may not be particularly good for the atomic energy industry, they did serve to get a lot of valuable information on the record.

The third article is the one based on the speech by Admiral Rickover (p. 78). We rarely publish speeches as such. But this one is so controversial and of such interest to the nuclear industry that we felt compelled to publish extracts from it. The interest in the talk was apparent at the Philadelphia Nuclear Congress last month where it kept cropping up in conversation. And to say that there was no unanimity of reaction to the talk would be the understatement of the year. It was not hard to find those familiar with the troubles on Oak Ridge's homogeneous reactor (that have set the reactor back one year) who would readily agree with Rickover's criticisms of reactor component suppliers. On the other hand, many equipment manufacturers exhibiting in Philadelphia were equally harsh in criticizing the government for being unrealistic in the requirements it imposes on industry. It is with this background that we present one of the harshest indictments yet of the nuclear industry by the man who is industry's biggest customer.

●

Editorial fare. Because NUCLEONICS has readers from all walks of nuclear life, the editors make a great effort to serve up a balanced diet of editorial coverage in each issue. Although we divide our subject coverage into nine basic areas, there are actually three broad areas that we cover: reactor technology, applied radiation, and instruments and measurements.

Once a year, in March, at the time of an annual meeting that the editors have with the NUCLEONICS advertising salesmen, we take stock to see, among other things, whether we followed the editorial formula we set for ourselves. The chart on this page shows that we achieved the article distribution we were seeking for 1956, a distribution that relates very well to the interests of our readers.—*The Editors*

Coming Features in NUCLEONICS

Next Month - Special Report, "Simulation and Computation in Nuclear Engineering"

Later Months - SPERT-III Reactor Facility
Modern Ways in Isotopic Analysis of Uranium

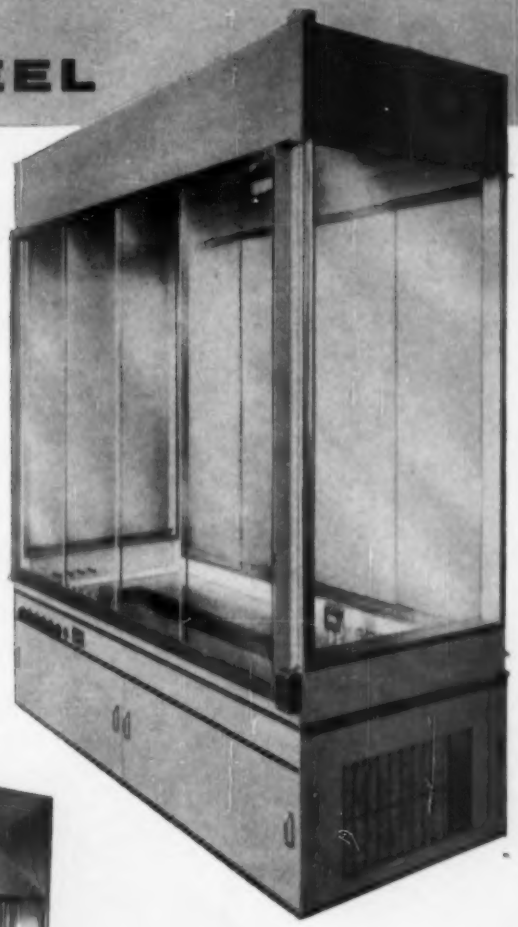
NUCLEONICS (with which is consolidated "Atomic Power" and "Atomic Engineering") April, 1957, Vol. 15, No. 4. Published monthly by the McGraw-Hill Publishing Co., Inc., Executive, Editorial, Advertising and Subscription Offices: McGraw-Hill Building, 330 West 42nd Street, N. Y. 36, N. Y. Publication Office, 212 East York St., York, Pa. Entered as second class matter December 17, 1947 in the Post Office at York, Pa., under the act of March 3, 1879. Copyright 1957 by McGraw-Hill Publishing Company, Inc. All rights reserved. Donald C. McGraw, President; Joseph A. Gerardi, Executive Vice President and Treasurer; John J. Cooke, Secretary; Nelson Bond, Executive Vice President, Publications Division; Ralph B. Smith, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator. **FOR SUBSCRIPTIONS,** write to Nucleonics-Subscription Service, 330 West 42nd Street, New York, 36, N. Y. Orders must indicate company and position. Allow one month for change of address. Price per copy $.75. Subscription rates: United States and U. S. Possessions $8 for 1 year, $12 for 2 years, $16 for 3 years. Canada $10 for 1 year, $16 for 2 years, $20 for 3 years. Other Western Hemisphere countries and the Philippines $10 for 1 year, $16 for 2 years, $20 for 3 years. All other countries $15 for 1 year, $25 for 2 years, $30 for 3 years. Member of ABC. Member of ABP.

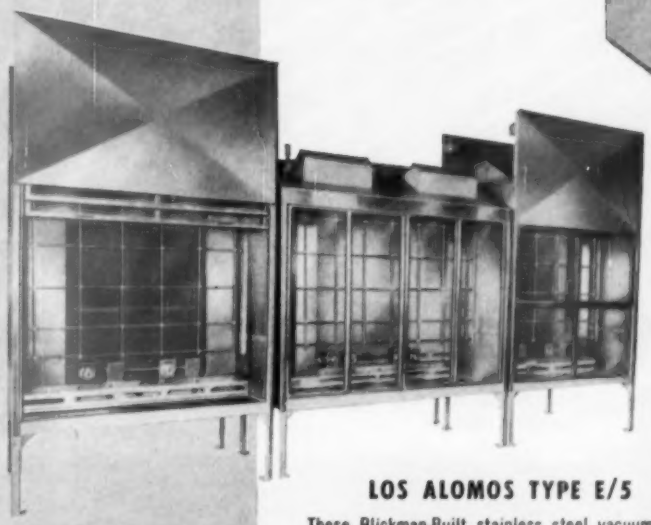
Blickman-Built

STAINLESS STEEL

VACUUM RACK ENCLOSURES

FOR HANDLING RADIOISOTOPES AND RADIOACTIVE MATERIAL





LOS ALOMOS TYPE E/5

These Blickman-Built stainless steel vacuum rack enclosures are designed for the safe handling of radioactive materials in research applications. Two types of racks are available.

TYPE E5-1 has a vertically-rising door. A similar door can be provided on the opposite side if operation from two sides is desired.

TYPE E5-2 has sliding doors with can also be provided on the opposite side for two-sided operation. Available in various lengths to meet specific requirements.

CALIFORNIA TYPE E/8

Seamless, crevice-free, round-corner construction assures easy cleaning, facilitates decontamination.

This Blickman-Built hood is designed for the handling of hazardous substances such as radioactive isotopes and other radioactive materials. The air supply to the hood is filtered through expendable type filters located at both ends.

Send for Technical Bulletin . . . also folder illustrating Blickman-Built Stainless Steel Specialized Laboratory Equipment.

Blickman-Built

Look for this symbol of quality

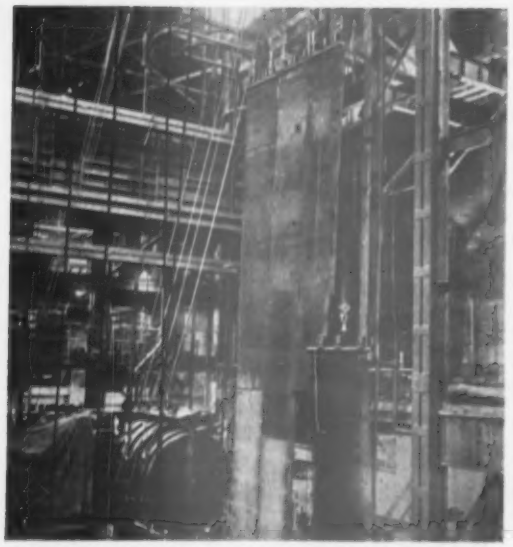
BLICKMAN

SAFETY ENCLOSURES

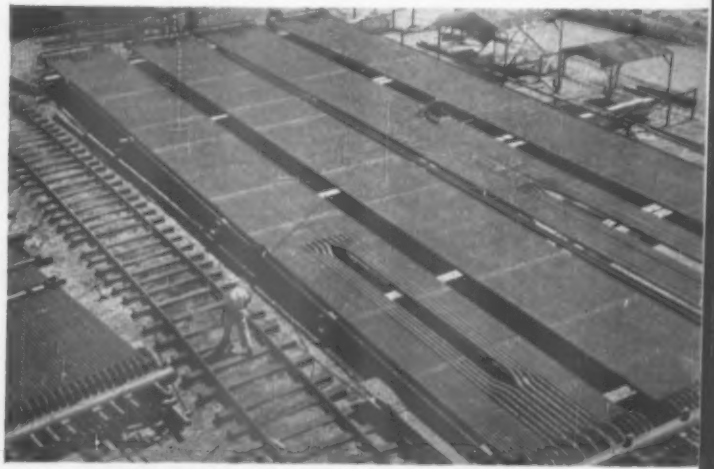
B&W AND ATOMIC ENERGY

How to Put

TONS OF CONCRETE, poured into this web of wire, will form walls of B&W-engineered swimming pool type research reactor.



SUPERCRITICAL pressure steam generator, the world's first, saw B&W engineers solve new design, fabrication, and erection problems.



ERECTION means smooth flow of components into place. Here side wall of high pressure, high temperature boiler is prepared for hoisting.

HERE ARE THE REASONS WHY B&W ENGINEERS KNOW...

a Nuclear Reactor Together

Putting a nuclear reactor together is an exacting engineering task. Research and power reactors are designed and fabricated to meet specific needs. But design and fabrication alone will not assure required operating characteristics. It's the job of the erection engineer to precisely assemble components into a working system.

SAFETY AND ECONOMY in assembling and testing research reactors and nuclear steam generating plants require skill in established construction methods. But with this skill, there must be combined advanced scientific and nuclear engineering techniques. B&W erection engineers have already acquired an extensive backlog of atomic energy experience, and are keeping up with the fast moving developments in the peaceful applications of this new source of energy.

LONG EXPERIENCE with high pressure vessels for example, has been applied by B&W to atomic energy's similar problems. It has been fortified by a continuing, independent program of nuclear research to make the Babcock & Wilcox position unique in design, fabrication, and erection for the atomic energy field.

STEP BY STEP, B&W engineers have followed progress in design and fabrication with improvements in erection methods. New techniques and tools have been developed and tested. Alloy welding, radiography, magnafluxing, and stress relieving processes have been adapted to the particular needs of erection.

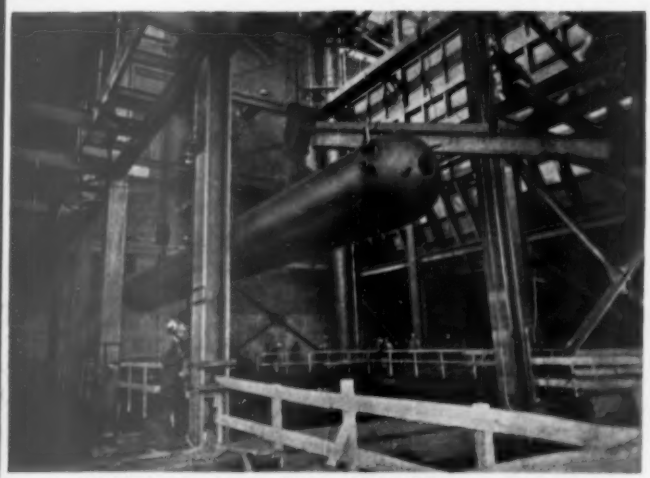
HIGHLY SKILLED EXPERTS with special training supervise erection. Precision is their watchword and the newest techniques are at their finger-tips. Behind them stand nearly 100 years of B&W experience and the entire chain of specialized B&W engineering skills.

COORDINATION of all B&W departments assures a continuity of responsibility in one company from planning to starting up operations. Write for Bulletin AED-6, "B&W Builds a Research Reactor." The Babcock & Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, N. Y.

BABCOCK & WILCOX

B&W

ATOMIC ENERGY DIVISION



KNOTTY erection problems, like hoisting a many-ton drum into position often over 100 feet above ground level, are taken in stride by specially trained engineers.

B&W'S STORE of high pressure welding experience is added to newest welding metallurgy refinements required for atomic energy projects.

AE-37-A

Think Of Everything – That sums up Electric Boat's "ICT". "ICT"–The "Integrated Concept Technique". No feasibility project can be handled sensibly if *all* elements, *all* possibilities are not treated simultaneously as a homogeneous factor.

For over 50 years–since the integrated concept of the original navy submarine "Holland"–to the reality of the first nuclear powered submarines, Electric Boat has expanded the "ICT". From simple to complex, "ICT" has now advanced to applications beyond weapons, noise suppression, simulation– to the remote areas of humanistics, thermodynamics and the correlation of concept to concept, complexity to complexity.

Electric Boat's experience in "ICT" can save you months–years in *your* feasibility work with the knowledge of years practically applied. We can adapt the Electric Boat "Integrated Concept Technique" to your feasibility problems.

ELECTRIC BOAT DIVISION

GENERAL DYNAMICS CORPORATION

Write to Dept. ICT4, GROTON, CONNECTICUT

new source for a big appetite!

from

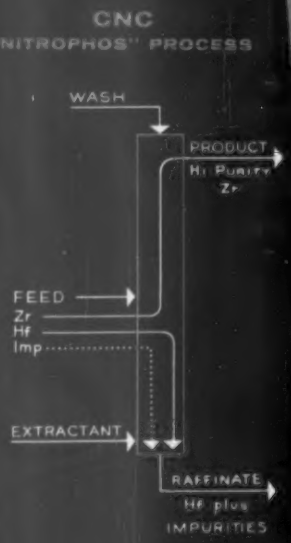
CNC ZIRCONIUM

The Zirconium Age has arrived! Columbia-National Corporation with its new sponge producing facility nearing commercial operation offers you a new source of zirconium at a new low price.

Uniform high quality zirconium is assured by the only fully integrated operation converting zircon sand to sponge at one location under the responsibility of one management. The unique "Nitrophos" extraction process is used to separate and purify zirconium and hafnium in this plant.

Reactor-grade and hafnium-containing commercial-grade zirconium sponge will be produced in sufficient quantities to fill government and industry requirements. Leading metal converters and fabricators are now supplying zirconium mill and finished products.

There is new opportunity in the Zirconium Age. You are urged to investigate its use in atomic reactors and in process equipment where corrosion conditions are severe. Columbia-National is ready to help with melting and application assistance. Write for technical data on fabrication, properties and corrosion resistance. Columbia-National Corporation, 70 Memorial Drive, Cambridge, Mass.



The new Columbia-National Zirconium Plant near Pensacola, Florida is the most modern in the world. The "Nitrophos" process continuously and automatically separates hafnium from zirconium and removes impurities, thus assuring uniform, high quality zirconium sponge.

ILLUSTRATION OF TYPICAL REACTOR CORE COURTESY WESTINGHOUSE ELECTRIC CORP.

Columbia-National Corporation

Jointly owned by Columbia-Southern Chemical Corp. and National Research Corporation

NEW METALS FOR INDUSTRY

ENGINEERS...LOOK TEN YEARS AHEAD!

A Douglas engineer lives here

Will your income and location allow you to live in a home like this...spend your leisure time like this?

They can...if you start your Douglas career now!

Your objectives are probably high professional standing, good income, good security and good living. All four can be achieved at Douglas.

Douglas has the reputation of being an "engineer's outfit," with the three top administrative posts being held by engineers. Maybe that's why it's the biggest, most successful unit in its field. Certainly it offers the engineer unexcelled opportunities in the specialty of *his* choice ...be it related to missiles or commercial or military aircraft.

You've looked around. Now look ahead...and contact Douglas.

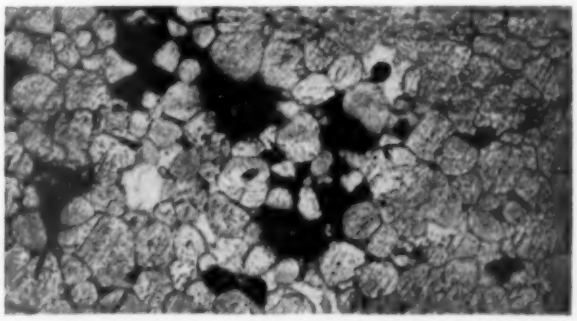
For further information about opportunities with Douglas in Santa Monica, El Segundo and Long Beach, California and Tulsa, Oklahoma, write today to:

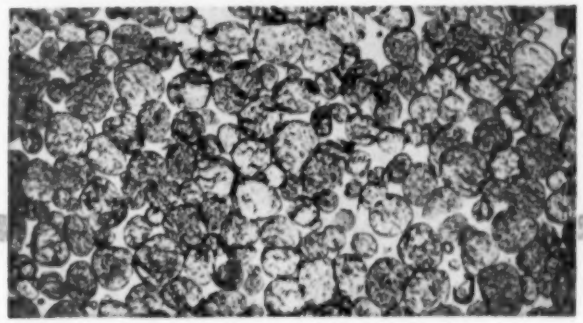
DOUGLAS AIRCRAFT COMPANY, INC.
C. C. LaVene, Box L-620, 3000 Ocean Park Blvd., Santa Monica, Calif.

DOUGLAS

First in Aviation

MALLORY





Under the microscope, ordinary shielding metals (above) reveal voids that seriously reduce radiation absorption . . . while Mallory 1000 Metal (below) shows high density, positive shielding all the way through.

Get predictable radiation shielding... with uniform Mallory 1000

THE HIGH DENSITY and superior radiation-absorbing capability of Mallory 1000 Metal extend through *every* part of *every* piece. Special Mallory manufacturing methods give this unique material an internal structure comparable in uniformity with forged metals.

To the designer of radiation shields, this superior uniformity permits calculations based on precisely controlled absorption characteristics rather than "average" or "typical" values. Safety factor allowances can be minimized to permit smaller parts and lower overall costs.

Mallory 1000 Metal is up to 40% more efficient than lead. It is being used at energy levels to 100 MEV, for source capsules, "switching" devices and similar purposes. Mallory contour pressing permits manufacture of intricate shapes to precise dimensions at economical cost. Mallory 1000 has high tensile and flexural strength, and machines readily to excellent surface finish.

For complete information, write to Mallory today for Technical Bulletin 6-7.

In Canada, made and sold by Johnson Matthey & Mallory, Ltd.
110 Industry Street, Toronto 15, Ontario

Serving Industry with These Products:

Electromechanical — Resistors • Switches • Tuning Devices • Vibrators
Electrochemical — Capacitors • Mercury and Zinc-Carbon Batteries
Metallurgical — Contacts • Special Metals • Welding Materials

Expect more... get more from

P.R. MALLORY & CO. Inc.
MALLORY

P. R. MALLORY & CO. Inc., INDIANAPOLIS 6, INDIANA

For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio

Laboratory cabinets courtesy of Chicago Apparatus Company

complete new instrumentation for biochemical research with radioisotopes

The modern laboratory illustrated above is the most complete and versatile ever assembled for nuclear biological research. Separate Nuclear-Chicago instruments have been combined into specialized counting and recording systems for scanning paper radiochromatograms, for assay of liquid or solid gamma emitting samples, for low level counting of carbon-14 and tritium, for automatic sample handling and counting. Each of these systems offers the maximum in accuracy and automaticity, is designed for integration with other biological techniques, and is built to maintain the traditional high standards of quality and reliability of all Nuclear-Chicago products. Our representatives will be happy to discuss your particular needs with you.

1A Rectilinear Recorder, **1B** Model C100A "Actigraph" with sensitive D47 Gas Flow Counter with exclusive "Micromil" window, and **1C** Model 1620A-S Analytical Count Rate Meter for automatic scanning and recording of the radioactivity on paper strip chromatograms.

2A Model 181A Royal Scaler and Model T1 timer are shown with **2B** Model DS5-5 Scintillation Well Counter for precision measurement of gamma emitting liquid or solid radioactive samples. Well counter contains a full 2" of lead shielding.

3A "Dynacon" Converter with 500 ml. ion chamber, **3B** "Dynacon" amplifier, and **3C** Recorder for high efficiency measurement of radioactive carbon-14, tritium, and other low level samples in the gas phase.

4A Printing Timer, **4B** Model 161A Basic Binary Scaler, and **4C** Model C110B Automatic Sample Changer for automatic handling, measuring, and recording of the radioactivity of as many as 35 samples. Thin window or gas flow detectors may be used with the sample changing system.

5A Model M5 Semi-automatic Sample Changer with Model D47 Gas Flow Counter connected to **5B** Model 186 Imperial Scaler. The 186 may be used with all G-M, scintillation or proportional detectors, features one millivolt to one volt input sensitivity.

nuclear-chicago
CORPORATION
223 WEST ERIE STREET • CHICAGO 10, ILLINOIS

Laboratory cabinets courtesy of Chicago Apparatus Company

complete new instrumentation for nuclear research in industry

The variety of research and manufacturing problems encountered in the modern industrial nucleonic laboratory requires the broadest range instrumentation, including counting systems for alpha, beta and gamma determinations. The new Nuclear-Chicago detection and recording equipment illustrated in the model industrial radioisotope laboratory above have been selected to handle a wide diversity of laboratory and plant problems and provide the ultimate in automatic sample-handling, recording and read-out convenience. Costly technical time is minimized in this model laboratory by automatic systems which collect precise data "around the clock". Your inquiries for specific recommendations will receive prompt attention.

1A Model DS5-3P Scintillation Detector with exposed 2″ x 2″ sodium iodide crystal and **1B** Model 132 Analyzer Computer for precision gamma-ray measurements using pulse-height discrimination techniques.

2A Model DS5-5 Scintillation Well Counter with exclusive "scaler-spectrometer" circuit and **2B** Model 1820 Recording Spectrometer for automatic quantitative energy separation of gamma-ray spectra.

3A Model 183B Count-O-Matic Binary Scaler, **3B** Model C110B Automatic Sample Changer with Model D47 Gas Flow Counter, and **3C** Model C111B Printing Timer for completely automatic changing, counting, and recording of as many as 35 soft beta emitting radioactive samples.

4A Model 3054 Manual Sample Changer with Model DS5 Scintillation Detector which features interchangeable alpha, beta, or gamma sensitive crystals connected to Nuclear-Chicago's finest scaler, the **4B** Model 192A Ultrascaler. Model 192A features decade scale of 10,000, one millivolt sensitivity, and precision automatic circuitry.

5 Model 2612P Portable Survey Meter contains a 1.4 mg/cm² thin window G-M tube for surveying for alpha, beta, or gamma contamination up to 20 milliroentgens per hour.

6 Model 2586 "Cutie Pie" features interchangeable ionization chambers for measuring beta, gamma, or x-radiation up to 250 roentgens per hour.

7 Model 1620A-S Analytical Count Rate Meter offers a wide choice of full scale ranges, four time constants, wide range high voltage supply. It is shown with a Model D34 thin window G-M tube and P11 probe for continuous monitoring or analytical radioactivity determinations.

A PRIME OUTLET FOR GOOD PUBLIC RELATIONS

and a desperately-needed public service

One of the most effective public relations jobs ever accomplished was achieved last year by hundreds of companies and individual businesses of every size.

These companies have been helping to sustain an advertising campaign that performs a desperately-needed public service: It shows the American people how to drive to stay alive. It also portrays the almost unbelievable fact that more than 40,000 men, women and children were killed in traffic accidents last year—and tells what to do to help stop highway homicide.

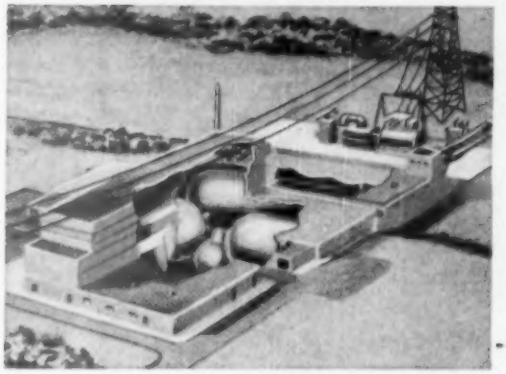
The campaign was prepared by a volunteer advertising agency in cooperation with The Advertising Council and The National Safety Council. But the over ten million dollars worth of time and space which carry the messages to the public was contributed by media owners or sponsored by business organizations, in the public interest.

Your own plans may readily permit the inclusion of such advertising—both from the view of the vital public service it would perform, and the incalculable good will it would promote for your name, your company, and your product or service.

To find out how easily your own program can tie in with this nationwide effort, and for the complete story on who, what, when and where, we sincerely invite you to write to The National Safety Council, Chicago 11, Illinois.

Published in cooperation with
The National Safety Council
The Advertising Council

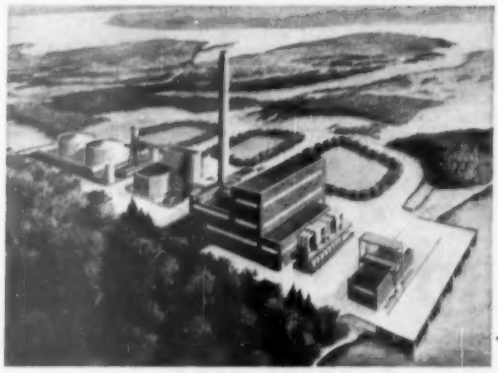
Three of America's LARGEST ATOMIC POWER PLANTS will use MAJOR COMPONENTS* by FW



60,000 KW SHIPPINGPORT PLANT
of the AEC and Duquesne Light Company

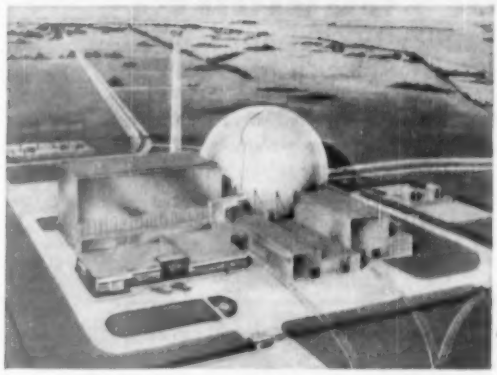
*Steam Generators. Two of the four steam generators for America's first full scale commercial atomic power plant have been designed and fabricated by Foster Wheeler. They will convert heat from the pressurized water reactor into steam for operating the turbo generator.

*Pressurizer. Also supplied by Foster Wheeler is the 18-ft high, 300 cu ft pressurizer used to maintain coolant loop pressure. It is designed for 2500 psig at 675 F and contains 342 electric immersion heaters for controlling operating pressure.



236,000 KW INDIAN POINT PLANT
of the Consolidated Edison Company

*Separately-Fired Superheaters. Saturated steam from the pressurized water reactor will be superheated from 447F to 1000F by two Foster Wheeler oil-fired superheaters, each with a capacity of 1,075,000 lb/hr at 410 psia. Compared to operation with saturated steam direct from the reactor, addition of the superheat cycle will raise plant capacity from 140,000 kw to 236,000 kw and reduced estimated plant cost from $322 to $233 per kw.



180,000 KW DRESDEN STATION
of the Commonwealth Edison Company

*Primary Steam Separator. Primary steam generated in the reactor will be separated from the water in a Foster Wheeler steam drum designed for a pressure of 1250 psia and capable of delivering 1,400,000 lb/hr at 1000 psia with moisture content of not over 0.1%.

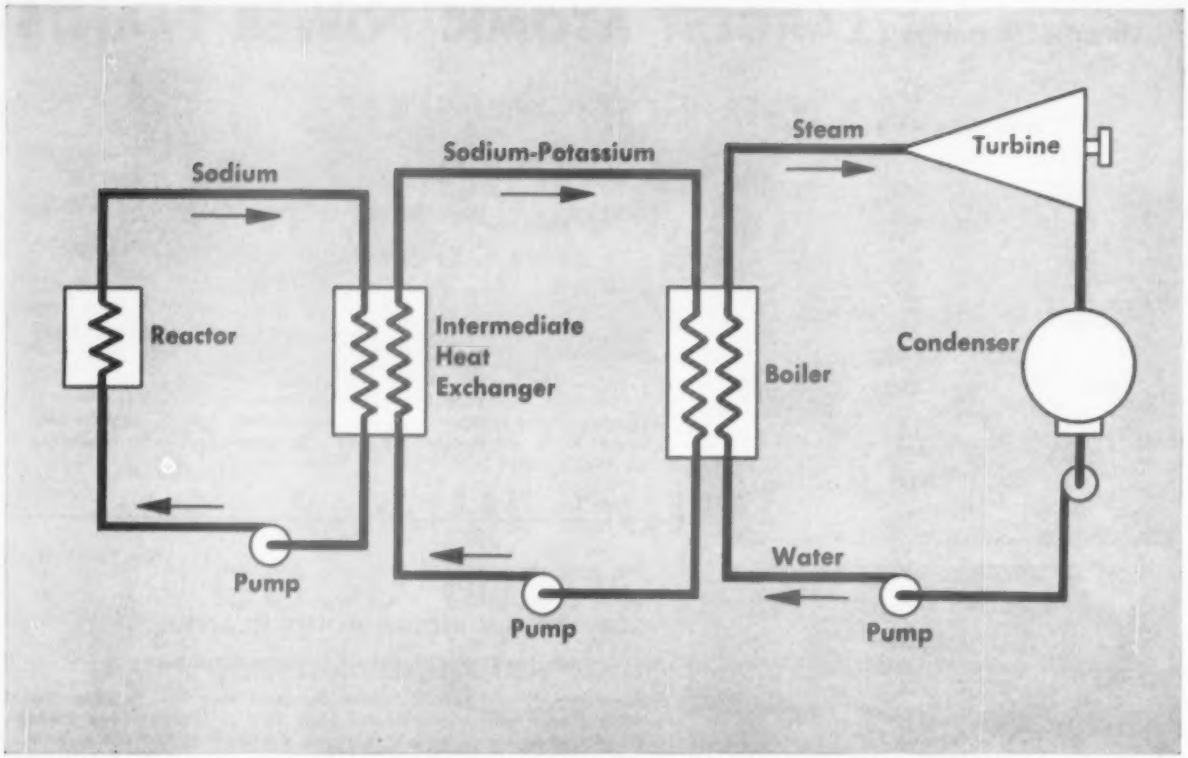
*Secondary Steam Generators. Primary nuclear heated water will be converted to secondary steam for a reduced-pressure turbine stage by four Foster Wheeler steam generators with a combined capacity of approximately 1,190,000 lb/hr at 510 psia saturated.

IN addition to the above major nuclear components, Foster Wheeler know-how encompasses the design and fabrication of complete nuclear power plants of the aqueous homogeneous reactor type as well as specialized tank-type research reactors.

For further details on any of these items, write to *Foster Wheeler Corporation, 165 Broadway, New York 6, N.Y.*

FOSTER WHEELER

NEW YORK • LONDON • PARIS • ST. CATHARINES, ONT.



What makes LIQUID SODIUM a first-rate Reactor Coolant?

At least 6 nuclear power plants now completed, planned, or under construction will use sodium metal in liquid form to transfer heat from reactor to steam generation circuit. Why have the designers of these systems selected sodium for the job?

Because sodium is a liquid from 207° to 1621° F., a sodium-cooled system can operate at high temperatures without expensive pressurization. In this way it can yield steam cycle efficiencies equivalent to those of conventional power plants.

Liquid sodium can be pumped and circulated as easily as water. Further, because liquid sodium has good electrical conductivity, it can be circulated with an electromagnetic pump containing no moving parts. With the low melting point of 207° F., it won't solidify in the heat exchanger system if the reactor is slowed down.

Sodium has high heat conductivity, as well as good radiation stability and high temperature stability. In the absence of oxygen, water, and other impurities, it can be handled without corrosion in iron and steel equipment.

U.S.I. supplies more sodium to outside industry than any other producer of the metal. For complete information on sodium and its handling, send for the free 40-page booklet "HANDLING METALLIC SODIUM ON A PLANT SCALE".

SOME REACTORS WHICH WILL USE SODIUM:

(1) **California**—sodium-graphite reactor, 7,500 kw
(2) **Nebraska**—sodium-graphite reactor, 75,000 kw
(3) **Idaho**—fast breeder reactor, 15,000 kw
(4) **Michigan**—fast breeder reactor, 100,000 kw
(5) **Alaska (Anchorage)**—sodium-deuterium reactor, 10,000 kw
(6) **Seawolf**—sodium-beryllium reactor
(7) **New York**—sodium-beryllium reactor

Chemical Progress Week — April 8-12

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers Products Corporation
99 Park Avenue, New York 16, N. Y.

FREQUENCY STANDARDS

AVIONIC
FREQUENCIES
PRECISION FORK

TYPE 50

FREQUENCIES
240–400–500–1,000 cy.

ACCURACIES
Type 50 ±.02% (—65° to 85°C)
Type R50 ±.002% (15° to 35°C)

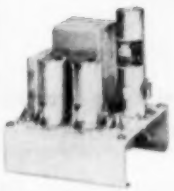
Requires double triode and 5 pigtail components

Size, 1" diameter x 3¾" high
Weight, 3.5 ounces

POWER
75 Watt
FREQUENCY STANDARD
TYPE 211C

FREQUENCIES: .....50 to 1,000 cycles
ACCURACY: ..±.002% (+15° to +35°C)
OUTPUT: .....115V, 75 Watts
INPUT: .....110V, 50 to 75 cycles
SIZE: with cover....10"x17"x9" high
PANEL model,..10"x19"x8¾" high
WEIGHT: .....25 pounds

INDUSTRIAL



FREQUENCY STANDARD
TYPE 50L

FREQUENCIES
50–60–75 or 100 cy.

ACCURACIES
TYPE 50L
±.02% (—65° to 85°C)
TYPE R50L
±.002% (15° to 35°C)

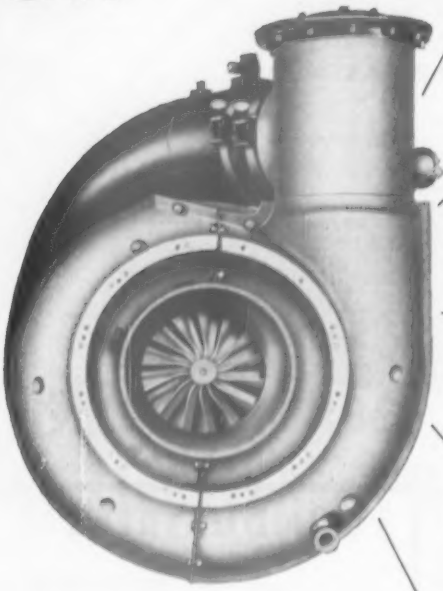
INPUT: 150 to 300V, B (6 V at .6 amps.)
OUTPUT: .....2V into 200,000 ohms.
SIZE:..3¾"x4½"x5½" high. Wgt., 2 lbs.

This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government, (armed forces) where maximum accuracy and durability are required.

American Time Products Inc.
580 Fifth Avenue, New York 36, N. Y.

American Time Products, Inc.
580 Fifth Ave., New York 36, N. Y.
Gentlemen: Please send details on your Type_____
Name_____
Company_____
Address_____
City_____

Mars* *is moving fast!*



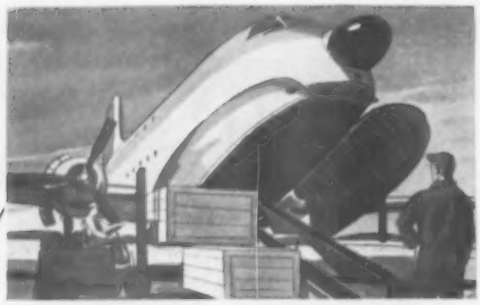
Mars engine has proven its worth in more than 15 applications.

Many new uses for the compact, reliable 50 hp Mars gas turbine have been developed in the last few years. Engineers welcome the high power-to-weight ratio of the Mars turbine, its fast starting under extreme temperatures, its easy maintenance, its sturdy dependability with infrequent overhauls. If you need a reliable 50 hp prime mover for pumps, auxiliary electric power or compressors, write Dept. C-145, Solar Aircraft Company, San Diego 12, Calif.

SOLAR AIRCRAFT COMPANY

SAN DIEGO
DES MOINES

*Mars is the registered trade mark of Solar Aircraft Company for its 50 hp gas turbine engine.



Auxiliary power for ground, air operations

Reliable fire fighting pumps

Hydraulic checkout for aircraft

Guided missile ground support

Pod-mounted electric power supply

Maybe that *special material* you need is . . .

ALITE

Throughout industry, design engineers are discovering the remarkable qualities of Alite — and are using Alite's unusual combination of desirable properties to improve existing products or create new ones.

The Alites are a series of high-alumina ceramics especially developed by U. S. Stoneware to meet the demands of higher thermal shock resistance, greater mechanical strength, and better electrical properties, to name just a few. Alite is vacuum-tight, can be metalized and fabricated into hermetic ceramic-to-metal assemblies for rugged service in a host of critical applications, both electrical and mechanical.

If you have a materials problem in the mechanical, electronic or nucleonic fields, designing for Alite could well be the answer. We invite inquiry on your specific applications.

Have you been looking for a material with properties such as these?

- **Superior mechanical strength**
- **Extreme hardness**
- **Exceptional abrasion resistance**
- **High temperature stability**
- **Excellent dielectric characteristics**
- **High corrosion resistance**
- **Resistant to nuclear radiation**
- **Workable to precision tolerances**

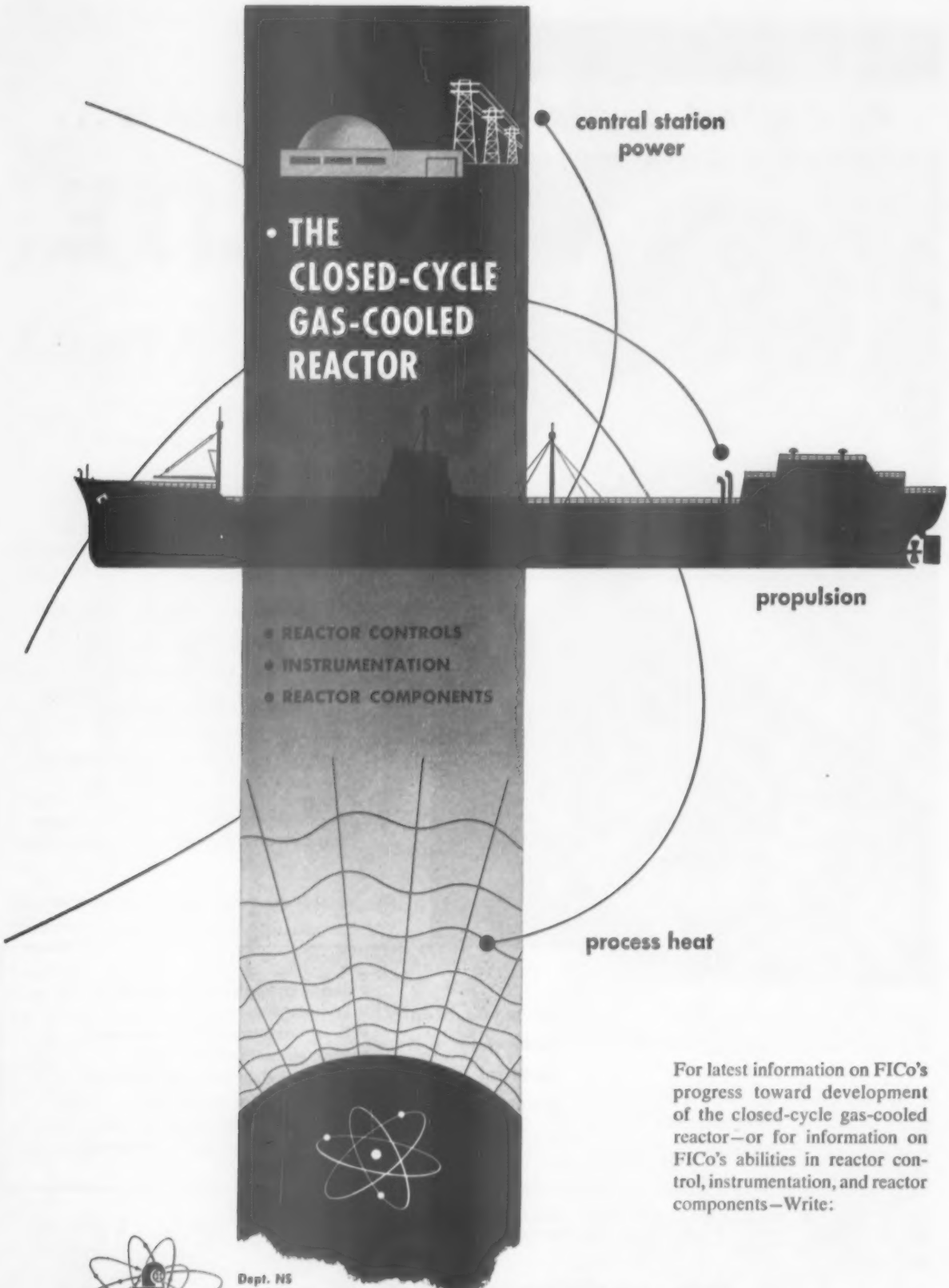
Write for this FREE idea starter

Bulletin A-7R gives advantages and possibilities of Alite, plus complete comparative data.

ALITE DIVISION

U. S. STONEWARE
AKRON 9, OHIO

1-9

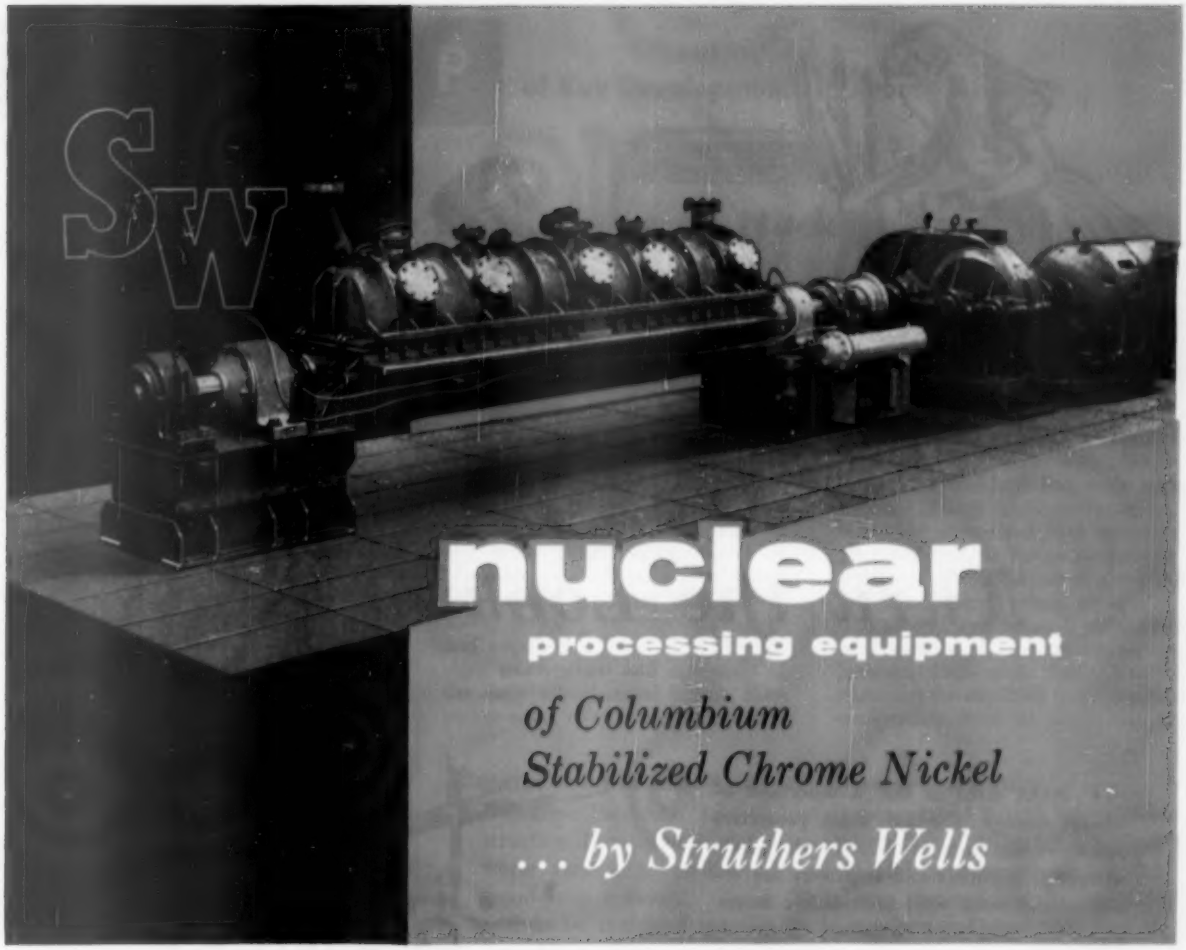


For latest information on FICo's progress toward development of the closed-cycle gas-cooled reactor—or for information on FICo's abilities in reactor control, instrumentation, and reactor components—Write:

Dept. NS

FORD INSTRUMENT CO.

DIVISION OF SPERRY RAND CORPORATION • 31-10 THOMSON AVENUE, LONG ISLAND CITY 1, N. Y.



EXPERIENCED,
EQUIPPED AND MANNED,
FOR THE DESIGN,
FABRICATION AND WELDING
OF SPECIAL NON-FERROUS ALLOYS

A recent example of Struthers Wells ability to design, fabricate and weld, using the special non-ferrous alloys, is this intricate machine for the processing of nuclear materials. This equipment was fabricated from Columbium stabilized Chrome Nickel to provide an ultimate of strength and corrosion resistance at extremely high temperatures. It features oil-cooled shaft bearings and agitators driven by 150 hp variable speed motors. The vessel trough was fabricated from one-inch thick plate with a heavy flange around the top.

This is typical of the special equipment designed, welded and fabricated by the experienced personnel of Struthers Wells Corporation, whose complete facilities include unusually adequate equipment for stress relieving, annealing and quenching.

STRUTHERS WELLS PRODUCTS

PROCESSING EQUIPMENT DIVISION

Crystallizers . . . Direct Fired Heaters . . . Evaporators . . . Heat Exchangers . . . Mixing and Blending Units . . . Quick Opening Doors . . . Special Carbon and Alloy Processing Vessels . . . Synthesis Converters

BOILER DIVISION

BOILERS for Power and Heat . . . High and Low Pressure . . . Water Tube . . . Fire Tube . . . Package Units

FORGE DIVISION

Crankshafts . . . Pressure Vessels . . . Hydraulic Cylinders . . . Shafting . . . Straightening and Back-up Rolls

MACHINERY DIVISION

MACHINERY for Sheet and Structural Metal Forming . . . Tangent Benders . . . Folding Machines . . . Roller Table and Tumble Die Bending Machines . . . Press Brakes . . . Punching and Notching Machines . . . Forming Dies

STRUTHERS WELLS Corporation

WARREN, PA.

Struthers Wells

Plants at Warren and Titusville, Pa.

Representatives in Principal Cities

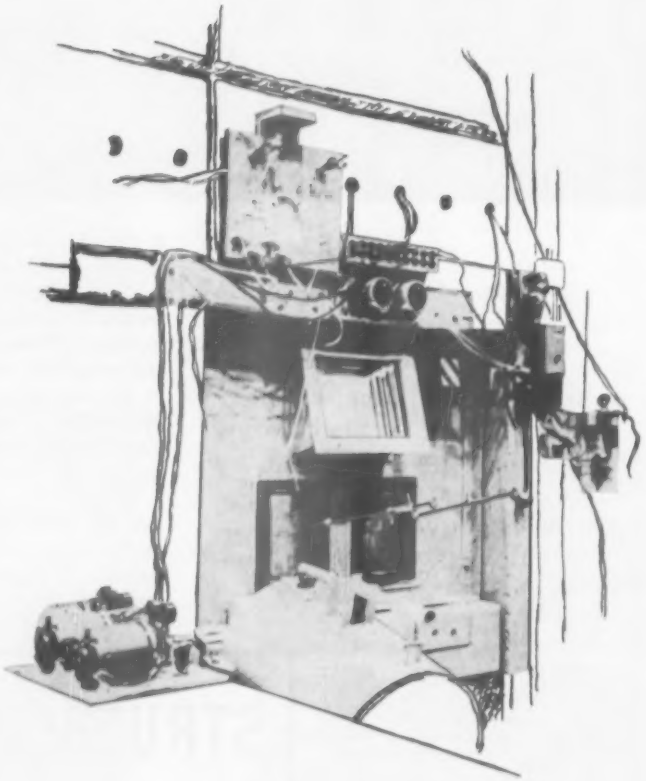
A
LOOK
AT
NDA

Thru the Looking Glass

• NDA lives in the Wonderland of atomic energy. Through thick protective windows like these at NDA-Pawling Laboratories, scientists and engineers can examine and work with radio-active materials. The effects of radiation on atomic fuels vital for military and civilian atomic power are studied.

• Advanced knowledge is constantly sought and found with safety despite the hazards of radioactivity. In the Radioactive Materials Laboratory, NDA has installed flexible facilities of unique design. Despite thick walls of lead, concrete, and glass, experiments can be built quickly, performed easily, and dismantled without disruption of satisfactory operations in adjoining facilities.

• Among projects being forwarded by NDA are a high-powered testing reactor for Belgium and an atomic power plant of advanced design known as the Sodium Deuterium Reactor (SDR). Assistance is also being given to numerous other military and civilian atomic power projects.



NDA—

NUCLEAR DEVELOPMENT CORPORATION of AMERICA
5 NEW STREET, WHITE PLAINS, NEW YORK
TELEPHONE: WH 8-5800

ROUNDUP of Key Developments in Atomic Energy

AEC Seeks to Allay Bearishness on Nuclear Power

A mood of disillusion, mild but unmistakable, seemed to hover over the industry at the Nuclear Congress in Philadelphia last month—continuation of a trend that was first noted at the last previous industry-wide meeting six months ago. But AEC's top reactor experts, almost as if they had foreseen this, offered a reassuring look into the future.

The week-long session at Philadelphia was surely the biggest nuclear meeting yet held in the U. S. The four-ring circus brought together in cavernous Convention Hall the 2d Nuclear Engineering and Science Conference (158 papers in four days), the 5th National Industrial Conference Board meeting on Atomic Energy in Industry (67 papers in two days), the 5th Hot Lab Conference (63 in two), and the 3rd International Atomic Exposition (118 exhibitors). More than 3,000 attended the N.E.S.C., and 1,600 registered for the N.I.C.B. sessions (with considerable overlap, of course).

Davis-Roddis Forecast

The forecasts by W. Kenneth Davis, director, and Louis H. Roddis Jr., deputy director of the Division of Reactor Development at AEC, were higher than any made previously by authorities in the field. Their report came as the bright spot at a meeting where the mood of sobriety, perhaps in certain cases even disenchantment, that was first noted at the Atomic Industrial Forum conference in Chicago last September (NU, Oct. '56, R6), was still in evidence.

That the size of their forecasts was no accident was made explicitly clear by Davis and Roddis: "Our estimates of long-range future nuclear capacity and output [*see Table, p. 18*] are somewhat higher than those we made two years ago and substantially higher than those made by some of our fellow forecasters. To a large extent, these higher estimates are explained by higher expectations regarding total utility installations, both nuclear and non-nuclear."

Davis and Roddis began by offering a long-needed definition of geneology in power reactors. They see the plants that will go into service in 1957 through 1959 as belonging to an **experimental period** in which there is no hope of approaching competitive power, in which costs may run from 20 to as high as 50 mills/kwh. The **first generation** of true industrial nuclear power plants will come on stream in 1960 to 1964, building on the technology and experience accumulated in design, construction and operation of the early experimental plants; their power costs, after initial shakedown, will run 10–13 mills/kwh (assuming 1957 price levels). Capital costs of $300–$400/installed kw as compared with $115–$180 for coal-fired plants, high costs of obtaining safety because little factual information is available, use of expensive materials for lack of experience with cheaper substitutes, and high fuel cycle costs because of high fabrication costs and relatively short-lived fuel elements, all contribute to the estimated discrepancy as of 1964 between nuclear and conventional power costs.

A second generation is considered to consist of plants entering service between 1965 and 1967. Capital costs may be expected to approach a competitive level as plant size in-

Reactor to make cobalt, process steam—and profits

Isotope Products, Inc., of Buffalo announced it will begin construction this summer, for operation in fall of 1958, of a boiling water reactor to produce cobalt-60 and process steam for the wood-pulp industry. Three "firsts" are claimed for the project: first to be designed specifically to produce radioisotopes; first in America, perhaps the world, to supply process steam for industry, and first "constructed solely for the purpose of returning a profit now." Designed by Walter Zinn's General Nuclear Engineering Corp., the unit will produce 1-million curies/yr of Co^{60} and 50,000 lb/hr of 200 psi steam. Sale of the former is expected to return $2-million/yr; the latter will be supplied to a pulp and paper mill. Negotiations are underway for steam sale and site location with "nearly a dozen" firms in the high fuel cost areas of New England, the midwest and Ontario, but identity of "several very substantial corporations" participating in the project was not disclosed, nor was the cost of the reactor. The core will be of special design to optimize Co^{60} and steam production, and the control system is also unique; no experimental facilities will be provided, the project being conceived as a straightforward chemical production plant.

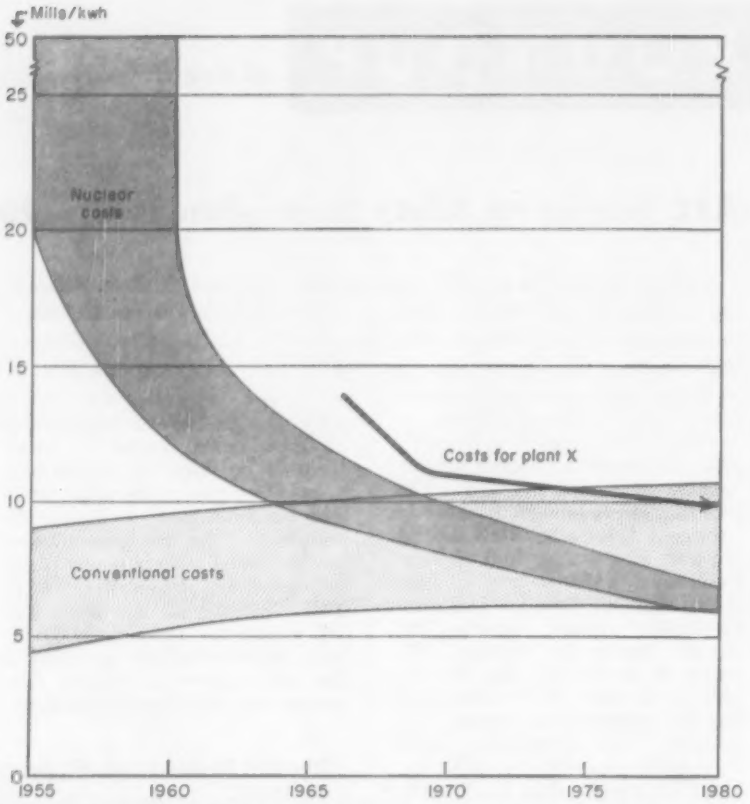
Westinghouse, GE active in Orient

Westinghouse is in final stages of negotiations with Mitsubishi Electric Co. of Japan on a $1-million technical-aid-and-parts deal for a pressurized water power reactor. Mitsubishi wants to fabricate as much itself as it can, would import from Westinghouse the fuel elements, shield, pressure vessel, control rods, rod drive mechanism, coolant pumps, and special materials.

NUCLEONICS learns also that a deal is pending between Tokyo Shibaura and General Electric; and that Westinghouse will sell a small pressurized water power reactor to Taiwan (Formosa) if the touchy financing problem can be solved.

creases, less costly materials are used, and more knowledgeable approaches to safety needs made. Fuel fabrication and fuel life problems may still require further solutions. Nevertheless, say Davis and Roddis, "plants going into service toward the end of this generation, after their initial shakedown, should achieve costs in the range of 9–11 mills. Considering further cost reductions to be expected during the lifetime of the plants, they should be competitive with modern conventional plants in at least some parts of the U. S." This compares with the McKinney Report forecast: "Decisions made on the basis of data which should be available around 1960 could result in economically competitive atomic powerplants coming into operation 3 to 5 years later, or around 1965. Thus 1965 marks, approximately, the earliest time at which widely-competitive atomic power generation is likely to begin in the U. S."

Following the second generation, say Davis and Roddis, further cost reductions will take place, "reaching a range of 6 to 7 mills by 1980. This would make nuclear power competitive with conventionally fueled plants in all parts of the U. S. except a few locations with very low fuel costs."



DAVIS-RODDIS COST CURVES. Chart also illustrates fact that for any hypothetical plant X, initial operating costs are higher due to special start-up problems; chart estimates are based on "stabilized" costs discounting this factor

Amounts of Nuclear Power

The experimental period reactors will total only 130 Mw installed capacity and nearly all of that from the only large-scale plant in the group, the Shippingport PWR. For the first generation ending 1964, Davis and Roddis foresee 2,500 Mw [their list of 18 first-generation projects includes four actually under construction (Con Edison, Commonwealth Edison, PRDC and Yankee); one almost two years under development (PAR); five awaiting conclusion of contract negotiations with AEC (Consumers of Nebraska, Elk River, Wolverine, Piqua, and Chugach); five announced as definite intentions (Florida group, Carolinas-Virginia group, Middle South, New England Electric System, and Northern States Power group); and three under consideration (Ohio Valley group, Pacific Gas & Electric, and Pacific Power & Light group)].

Toward the end of the first generation, the AEC leaders expect "a turning point when a fairly large number of power producers and equipment manufacturers will become confident that plants can be planned and designed which will be economic when built and successfully operated over a long period of time during which coal and oil prices would be increasing slowly. This turning point may be partially psychological in nature, although based to a considerable extent on scientific and engineering judgment."

Several years will be required for this turning point to take effect, because of the lead time needed between first planning and final completion of a nuclear station. Once that happens, however, the nuclear-fueled proportion of total additions each year to power capability will rise steadily from about 8% in 1967 to about 66% by 1980; after that 13-year expansion phase, percentage of nuclear additions to the grid will decline as it approaches saturation. "The non-nuclear portion may be expected ultimately to hold steady at about 25% of capacity added each year, in the form of hydro plants, very small plants, or plants located where fossil fuel costs are very low."

AEC's Crystal Ball

On the basis of these "key expectations," Davis and Roddis present

Forecasts of Installed Nuclear Capacity*

	1960	*1965*	*1970*	*1975*	*1980*
Davis and Roddis, March 1957	0.8	4.0	22.6	88.9	227.2
Davis, April 1955	0.8	4.5	27.0	83.0	175.0
James Lane, Oak Ridge National Lab., 1953	0.5	—	12.0	—	42.0
McKinney Report, Jan. 1956—					
Upper range	0.8	4.0	9.0	45.0	135.0
Lower range	0.8	3.0	9.0	20.0	52.0
B. R. Prentice, General Electric Co., for McKinney panel, Nov. 1955	0.8	4.0	12.3	48.0	137.8

* All figures in thousands of megawatts electrical.

this look into the future of U. S. power generating capacity:

Year	Total capability ($Kw \times 10^6$)	Nuclear capability ($Kw \times 10^6$)	Nuclear as % of total
1957	130.8	0.08	0.1
1960	175.3	0.8	0.5
1965	251.7	4.0	1.6
1970	360.3	22.6	6.3
1970	500.0	88.9	17.8
1980	700.0	227.2	32.5

Total energy output from nuclear plants will involve slightly higher percentages than installed capacity, as nuclear plants may be expected to operate at higher average load factors than the average of conventional plants, Davis and Roddis point out.

"This is a period of some discouragement with respect to the cost of building and operating power reactors," said the AEC officials in conclusion. "After the excessive optimism of two or three years ago, we are at grips with the hard realities of developing and building real nuclear power plants. This does not turn out to be an easy task. There are many difficulties and the way ahead is not wholly clear. However, just as it was unfortunate to have had this overoptimism two or three years ago about 4- and 5-mill nuclear power, it would be equally unfortunate to let the present frustrating but not unexpected engineering difficulties lead us to undue pessimism about the future of nuclear power in the U. S.

"Some years from now, we believe that nuclear plants will have higher capacities than the present conservative designs permit and that they will be built more simply and more cheaply. We believe also that we will find ways of making fuel elements of long life cheaply and with adequate reliability. Some of this, perhaps the major part, will be accomplished simply by dogged engineering development work. The rest will come from the new ideas and inventiveness that have ever characterized the advance of technology in the U. S.

"These advances will take time, money, facilities, and, most importantly, they will require the best engineers and scientists working in the most effective manner. We acknowledge that in the light of present-day knowledge, the estimates we have presented may appear optimistic. They depend upon vigorous and successful prosecution of the present development program. They assume a fertile climate for the growth of a nuclear power industry in the U. S. The history of similar developments in the past fully justifies our optimism.

"We must be realistic about the task that lies ahead and the problems that must be solved. Let us be optimists—but realistic optimists. We believe that the task can be and will be accomplished."

Durham Asks More Vigor In A-Power Development

Joint Committee chairman Rep. Carl T. Durham weighed in with criticism of the A-power program, in an address suggestively entitled "Some Realism on Atomic Power Development." Apologizing at the outset ("I am in a sense stepping a bit out of character, for I am one of

Alco gets Alaskan reactor design job

Alaskan District Corps of Engineers has awarded a design contract to Alco Products for a power-and-heat reactor for a military installation, according to a NUCLEONICS dispatch from Anchorage. Last summer Congress voted $500,000 for such a design job (NU, Aug. '56, R9). Size and site were not disclosed, but expectations are that it will be a $4-million, 1.5-Mw modified APPR for the Big Delta in interior Alaska.

Eisenbud among new IAEA aides

Merril Eisenbud, manager of New York Operations Office of AEC, is one of four scientists engaged by the Preparatory Commission of the International Atomic Energy Agency to aid an 18-man working group of senior experts in working out a program for the Agency's first year. He has taken three months' leave. His new colleagues are M. E. G. Bancora, physics professor and director of fundamental research of Argentina's AEC; Hubert de Laboulaye, technical advisor for foreign relations and senior physicist in the reactor development division of France's AEC; and D. M. Skorov, professor of metallurgy at Moscow Institute of Physics and Engineering. During its first session last month, the 18-man working group discussed reactor programs, isotopes, research, training, health and safety, exchange of information, and safeguards, as fields in which IAEA has an interest. U. S. delegate on this group is Richard L. Kirk, newly-appointed assistant director of international affairs at AEC; A. P. Zefirov represents the U.S.S.R. August 19 is tentative starting date for IAEA's first General Conference.

Chemical processing cost set

AEC has finally given an indication of what fuel reprocessing will cost: $15,300 will be the "standard daily processing charge" at a "conceptual plant capable of processing all the fuel elements types now known to be planned for use in power reactors." This is based on an assumed plant's construction costs of $20.6-million and annual operating costs of $4.6-million. The plant would be capable of handling one ton of natural or slightly enriched uranium daily, and would operate 300 days/yr, yielding purified nitrate salts of uranium and plutonium. Conversion to UF_6 or Pu metal will carry an additional charge, not yet set; $35/kg has been quoted by AEC to PRDC for converting uranyl nitrate hexahydrate to UF_6 at 2.5% enrichment. The price will be less for lower enrichment. AEC announced contract terms last month (NU, March '57, R3).

Brazilian power plant set for Rio area

Niteroi, across Guanabara Bay from Rio de Janeiro, has been selected as site for the 10-Mw nuclear power plant American & Foreign Power will install in Brazil (NU, Nov. '56, R6; March '57, R9). Brazil and Cuba will get General Electric boiling water reactors.

the greatest optimists about the present and future prospects for atomic energy development"), the North Carolinian laced into the Administration for the "stretch-out" on the nuclear plane program (NU, March '57, R6). "The Defense Department is again using the meat-axe instead of the scalpel on the Aircraft Nuclear Propulsion program," he said. "Here is a program where the sound principles of management have constantly been violated. Management has been indecisive with authority spread out among several different offices and branches. In the current cutback, no objectives, schedules or target dates have been set to provide guidance in the program."

Durham expressed concern over evidences of increasing nuclear power project costs presented to the Joint Committee in February (NU, March '57, R5). "These somewhat unpleasant facts raise a number of questions: Who is going to pay these increased costs? What are the implications as to the realities of private participation in atom power development during the next five or ten years?" Answering his own questions, Durham said it would probably be primarily the equipment manufacturer who will pay the increased costs, with some of them being shared by power operators "to be charged off through their rates." On the second question, he cited the recent Atomic Industrial Forum survey (NU, Feb. '57, R6) that showed the belief of industrialists that lack of financial incentive is their primary problem.

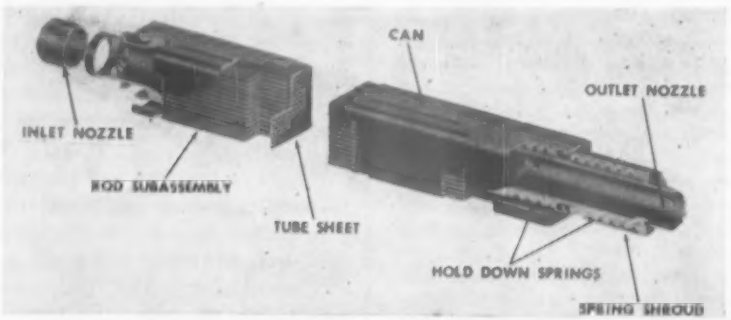
Durham also was upset over the problem of U. S. world leadership, which he feels is being seriously challenged—by the British, by the Russians, by Euratom. "Our atomic leadership has become a part of our foreign policy, whether we like it or not," he said. "The challenge and opportunity is there. I believe we can meet it. But we can't afford to wait another year or two. . . . This urgent need for atomic power in foreign countries offers a great opportunity for our domestic atomic equipment industry to get some experience and make some money in foreign markets until atomic power becomes more economic here. But . . . witnesses [at the 202 hearings] were practically unanimous that we need a far more aggressive program to back up our equipment suppliers in their efforts abroad. Red tape needs to be cut, and reactor projects need to be considered and sold as a package including fuel fabrication and reprocessing in order to compete with our friends abroad."

The JCAE chairman made six specific recommendations:

1. Construct an additional Pu-production reactor at Hanford, its waste heat tapped for power;
2. "Authorize development and construction of a Mark-I Flying Prototype of a nuclear-propelled aircraft with a realistic target date for completion";
3. Substantially more AEC funds for reactor research, development;
4. Inaugurate an accelerated domestic reactor demonstration program to ensure a variety of prototype power reactors operating in the U. S. by 1961–62;
5. Establish a foreign power-reactor demonstration program assisting friendly nations abroad and helping provide research and development aid and a foreign market for domestic equipment makers;
6. Enact the indemnity bill to cover liability for reactor accidents.

Recent Contract Awards On Nuclear Scene

Leeds & Northrup has been awarded contracts for the control systems of the Babcock & Wilcox pool research reactor for Brazil and of the Foster Wheeler tank research reactor for Denmark. The latter will be similar to the control system L&N designed for the Livermore pool reactor (also built by Foster Wheeler), although the Livermore pool will operate at 1 Mw and the Danish tank unit at 5 Mw. L&N also has built complete control systems for EBWR, ETR, the Geneva, Penn State, Michigan U., MIT, and Curtiss-Wright research reactors, and parts of others . . . Fluor Corp. will build one uncooled and two cooled 300,000-gal stainless steel tanks for storage of aqueous wastes at the Idaho chemical processing plant, for about $380,000. . . . Glenn Martin nuclear division has signed a contract with AEC to process 65 kg UF_6 into 50 kg UO_2. Martin Nuclear is nearing completion of facilities to fabricate this fuel into tubular elements; these are scheduled to undergo thorough testing by year's end. Similar tubular elements will be used in the 1–2-Mw, air-transportable Martin package power plant. . . . Fairchild Camera & Instrument Corp. has received a second Navy contract for design and fabrication of a portion of a transistorized power reactor control system, including all components of a power level measuring system reading out neutron flux from start-up through power ranges. This is the 15th contract for Fairchild's year-old nuclear instrumentation dept.; sales include two transistorized radiation monitoring systems comprising air particle monitors, gamma and neutron channels, for the Navy; naval reactor control rod drives; valve position indicators; a fuel element detector system and pitch-and-roll-compensating instruments for naval reactors.



New design for Indian Point first-core fuel element

Ceramic-type element (NU, March '57, R1) is designed for 600 days' lifetime at full power as against 365 for original plate type (Aug. '56, 70). Core loading will be 500 kg fully enriched U^{235} in form of UO_2, homogeneously mixed with 16,500 kg thorium oxide; 120 such elements will each be made up of 6 bundles of 206 fuel pins containing compacted powder fuel; elements are 11½ ft long, individual pins 0.3125 in. dia. Babcock & Wilcox's Alliance plant is carrying out physical and mechanical tests on element; a full-scale in-pile loop test will start shortly

Britain's First A-Sub: A New HMS Dreadnought

Britain's first nuclear submarine will bear a famous name, illustrious in the Royal Navy: Dreadnought. Vickers-Armstrong Ltd. will build the craft, the Admiralty's financial secretary, Christopher Soames, reported to Commons; an order has been placed with Vickers shipyard for construction of the prototype submarine, and Vickers Nuclear Engineering Ltd. is already well along with designs for her prototype reactor. Rolls-Royce and Foster Wheeler Ltd., co-founders with Vickers-Armstrong of Vickers Nuclear Engineering, will also figure prominently in handling engineering problems under general supervision of the Atomic Energy Authority. The joint firm has been engaged since its founding in February 1956 on development of propulsion machinery based on a pressurized water reactor. The three participating companies are pooling their experience and technical resources; Rolls-Royce is responsible for design of the reactor and associated equipment; Foster Wheeler for the steam generators and auxiliaries, and Vickers-Armstrong for the turbines, condensers, etc. As in the U. S., the prototype machinery will be installed in a land-based hull for preliminary testing and proving.

In another project, AEC is building a zero-power, organic-moderated experimental ship propulsion unit at Harwell. It is believed that this approach will result in an engine delivering power at a cost far below that of *Nautilus*.

AEC Licensing News

Licenses granted: Aerojet-General Nucleonics, to operate third AGN-201 reactor (serial 102), 3/14/57; fourth (serial 103), 3/29/57

Construction permits granted: North Carolina State College authorized to modify its research reactor, 3/6/57

Lockheed Aircraft Corp., Van Nuys, Calif., for critical facility, 3/14/57

Babcock & Wilcox, to construct and operate critical facility at Lynchburg, Va., 3/20/57

Export licenses issued: AMF Atomics, to export a 1-Mw pool to Munich, West Germany, 3/15/57

Application received: University of Buffalo, Buffalo, N. Y., to operate a 1-Mw pool, 3/11/57

Oklahoma A. & M., to buy and operate AGN serial 102, 3/20/57

Texas A. & M., to buy and operate AGN serial 106, 3/25/57

Cost of Huge British Program Yet to Be Clearly Fixed

After several postponements Britain has finally lunged into a nuclear baseload power program consisting of no less than 6-million Mw from 19 stations by 1965. Costing $2,520-million, it is the largest single industrial investment Britain has ever made, will save the equivalent of 18-million tons of coal, and supply 25% of the nation's power (forecast NU, Feb. '57, R7). But she so fumbled the announcement—four times the size of the original 1955 program, it is not to be the subject of a White Paper—that the *Economist* commented, "A Government that muffs the launching of a new atomic power program so badly as it did last week cannot altogether avoid the suspicion that it does not fully understand the implications of what it is doing."

Main confusion of the cost of the program sprang from Lord Mills' original statement in the House of Lords where, in answer to startled questions about the over-all cost of the nuclear program, he offered a figure of $4,088-million. At the subsequent press conference attended by Lord Mills, Lord Citrine, and other top government officials, it required a huddled conference at the top table to resolve that this figure did, in fact, include the cost of 12,900 Mw of conventional steam generating plant and some distribution costs for the same period.

There was no less confusion as to whether the $2,520-million nuclear cost figure eventually settled on included the fuel charges. As a result, three of Britain's most responsible dailies published widely differing versions of the program.

Cost Bases

In effect the capital cost per kilowatt of the plant and that of the fuel—which is considered separately as an operating charge—do not differ significantly from those on which the original 1955 program was costed. Thus 2,000 Mw at $353/kw for the plant sums to $694-million. Fuel cost rated at $81/kw sums to $162-million. Together they come to near the $840-million of the original program. For 6,000 Mw, three times this cost figure approximates the figure for the expanded program. About half the capital cost is swallowed up by the reactor vessel.

A big slice of the additional power results from conventional engineering development of the Calder Hall type—mainly 1. Larger reactor vessels—75 ft dia spheres, 50 ft dia cylinders as against Calder Hall's 37 ft dia vessel—which take twice the Calder Hall fuel load (500 tons in the largest); and 2. Doubling of heat extraction rates per ton of fuel by a 50% increase in gas coolant pressure. This feature is largely due to ability to site-weld 3-in. thick plate as against 2-in. plate at Calder. Together, these factors have by and large quadrupled output per reactor.

Recent statements by Sir John Cockcroft strongly indicate that all 19 stations will be gas-cooled graphite-moderated types, with later ones to utilize slightly-enriched uranium. It is also likely that ceramic fuel elements will be available towards the end of the period, operating at temperatures of 600–800° C. This would lead to such great increases in specific outputs that Sir John considers 1,000 Mw feasible from two reactors per station. By 1965 capital costs are likely to be well below $280/kw as a result.

Sites—and the Public

The Government is clearly worried about public reaction to station siting. Because of their great size and coolant thirst (considerably greater than that of a comparable coal station), sites will be restricted to river estuaries and the coast. No amount of government propaganda can mask the fact that several beauty areas in Britain must soon be downgraded—if only by the distribution system. There are not too many suitable areas in Britain, and of these some are too close to built-up areas to be acceptable in the present state of the art. The cliff coastline of southern England prevents use of sea-water cooling; flat coast regions are too populated—this rules out the Thames estuary. And of the areas not properly sited to exploit coal-burning plant, only the east coast south of the Wash and Bristol Channel's southern coast remain.

It is likely that two stations will be placed in Wales, if only for political reasons. According to Sir John Cockcroft, one method of reducing the number of sites will be to locate four reactors together where the water supply is adequate.

The Government is not likely to award any more contracts until the sites have been definitely fixed.

At month's end a spokesman told Commons that nuclear stations with ten times Calder's output—or 960 Mw—may become feasible.

The United States' Reactor Builders:

	Research & test reactors		*Power reactors*	
	Domestic	*Foreign*	*Domestic*	*Foreign*
ACF INDUSTRIES				
MIT (Cambridge)		Italy		
AFNETR (Wright-Patterson AFB)		Netherlands I		
Case Institute group* (Cleveland)		Sweden		
Bell Laboratories* (Whippany, N. J.)				
AEROJET-GENERAL NUCLEONICS				
21 AGN-201's			GCRE†	
ALCO PRODUCTS				
			APPR (Ft. Belvoir)	
			APPR-1A (Alaska)*	
ALLIS-CHALMERS				
			Northern States Power group	
AMF ATOMICS				
Battelle Memorial Institute‖ (Columbus, Ohio)		W. Germany (Munich)	RCPA (Elk River, Minn.)	Rheinisch-Westphälische Elektrizitätswerke (Essen, W. Germany)§
Buffalo U.		Netherlands II		
IRL (Plainsboro, N. J.)		Japan II		
Union Carbide (Tuxedo Park, N. Y.)		Greece		
		McMaster College (Hamilton, Ont.)		
ATOMICS INTERNATIONAL (NAA)				
WBNS (Downey, Calif.)‖		Japan I	SRE, (Santa Susana)	A. & F. P., Mexico§
LIWB (Livermore, Calif.)‖		Denmark II	CPPD (Hallam, Nebraska)	
Armour Research Foundation (Chicago)‖		W. Germany (Berlin)	OMRE (NRTS, Idaho)	
KEWB (Santa Susana, Calif.)‖		W. Germany (Frankfurt)	Piqua, Ohio	
UCLA*		Spain II		
BABCOCK & WILCOX				
Michigan U.		Brazil	LMFRE†	
		W. Germany (Hamburg)	Con Edison (Indian Point, N. Y.)	
			First merchant ship	
			Florida group†	
COMBUSTION ENGINEERING				
			S1C submarine	
DAYSTROM				
BNL Medical				
Curtiss-Wright (Quehanna, Pa.)				
Dart argonaut (West Caldwell, N. J.)				
FOSTER WHEELER				
Livermore pool		Denmark I	Wolverine (Hersey, Mich.)	

How to Read Reactor Alphabet-Soup

AFNETR	Air Force Nuclear Engineering Test Reactor	BNL	Brookhaven National Lab.	GCRE	Gas Cooled Reactor Experiment
ANL	Argonne National Lab.	CPPD	Consumers Public Power District	HRE-2	2d Homogeneous Reactor Experiment
ANP	Aircraft Nuclear Propulsion	EBR-2	2d Experimental Breeder Reactor	IRL	Industrial Reactor Laboratories Inc.
APPR	Army Package Power Reactor	EBWR	Experimental Boiling Water Reactor	KAPL	Knolls Atomic Power Lab.
Arbor	Argonne Boiling Reactor	ETR	Engineering Test Reactor	KEWB	Kinetic Experiment for Water Boilers
A. & F.P.	American & Foreign Power Co.	FIR	Food Irradiation Reactor		

Projects Built, Building or Ordered

	Research & test reactors		*Power reactors*	
	Domestic	*Foreign*	*Domestic*	*Foreign*
GENERAL DYNAMICS				
	3 ANP reactors	"Swing" reactor (Chalk River, Ont.)		
GENERAL ELECTRIC				
	ANP high-temperature	Spain I	Prototype boiling reactor (Vallecitos, Calif.)	A & F. P. Cuba§
	2 ANP Lockheed research reactors	Venezuela	Commonwealth Edison (Chicago)	A. &. F. P. Brazil§
	2 Thermal test reactor Washington State Coll.‡	Argentina	*Seawolf* prototype (S1G)‖	
			Seawolf (S2G)‖	
			Triton prototype (S3G)	
			2 *Triton* (S4G)	
			Destroyer prototype (D1G)	
			Plutonium recycle reactor	
KAISER				
	ETR (NRTS, Idaho)			
	FIR (Stockton, Calif.)			
MARTIN				
				Dominican Republic§
NUCLEAR DEVELOPMENT CORP. OF AMERICA				
		Belgian Test Reactor¶	SDR (Chugach), (Anchorage, Alaska)	
PHILLIPS PETROLEUM				
			SPERT-1 (NRTS)‖	
WESTINGHOUSE				
	WTR (Waltz Mill, Pa.)		PWR (Shippingport, Pa.)	Belgian Thermal Reactor
			Yankee Atomic (Rowe, Mass.)	Italy (Edisonvolta)§
			PAR (eastern Pennsylvania)	
			Nautilus prototype (S1W)‖	
			Nautilus (S2W)‖	
			2 S3W submarines	
			3 S4W submarines	
			7 S5W submarines	
			2 A1W carrier prototypes	
			8 A2W carrier reactors	
			2 F1W cruiser reactors	
FOLLOWING ACTED AS OWN PRIME CONTRACTORS				
	North Carolina State‖		Fermi reactor (PRDC)	
	Penn State‖		EBWR,‖ EBR 1 & 2, ALPR, Arbor,† Borax 4†‖ (ANL)	
	Naval Research Lab.‖ (Washington, D. C.)		HRE 1 & 2 (ORNL)	
	NACA (Sandusky, Ohio)		LAPRE, LAMPRE (LASL)	
	Omega West (LASL)‖			

° Design contract only.
† Power experiment, no turbine.
‡ Selected to design & build reactor, but no contract yet.
§ Bilateral agreement yet to be completed.
¶ Designers and advisors on fabrication & construction.
‖ Reactor completed and operating.

LAMPRE	Los Alamos Molten Plutonium Reactor Experiment	NROE	Naval Reactor Organic Experiment	PRDC	Power Reactor Development Co.
LAPRE	Los Alamos Power Reactor Experiment	NRTS	National Reactor Testing Station	PWR	Pressurized Water Reactor
LASL	Los Alamos Scientific Lab.	OMRE	Organic Moderated Reactor Experiment	RCPA	Rural Cooperative Power Ass'n.
LIWB	Livermore Water Boiler	ORNL	Oak Ridge National Laboratory	SDR	Sodium-Deuterium Reactor
LMFRE	Liquid Metal Fueled Reactor Experiment	PAR	Pennsylvania Advanced Reactor	SRE	Sodium Reactor Experiment
NACA	National Advisory Committee for Aeronautics			WBNS	Water Boiler Neutron Source
				WTR	Westinghouse Test Reactor

Reactor News

DEATH KNELL FOR KNOLLS' SUB REACTOR

SIR Mark A, the land-based *Seawolf* prototype reactor in the big steel sphere at West Milton, N. Y., has been deactivated and will be "disposed of." Contrary to some published statements, the prototype never worked well since it was started up in May 1955; in its current report to Congress, AEC says, "Since leaks developed in the superheaters, the prototype operated at 40% of rated power with the leaking superheaters by-passed. Cause of the leaks remained to be determined." The General Electric-operated Knolls Atomic Power Laboratory, which developed the sodium-cooled SIR (Submarine Intermediate Reactor), has been assigned a new project: a pressurized water reactor for destroyers (NU, March '57, R3). Deactivation of SIR-A follows a Department of Defense statement that it does not plan to install sodium-cooled reactor systems in any other naval vessel, and that experiments to develop operating information required for the sea trials of *Seawolf* have been completed. "Plans for the disposal of the reactor and equipment at West Milton are being prepared by the Commission," AEC said. However the 225-ft dia steel sphere will be retained intact "for future use in experimental operation of prototype nuclear power plants." AEC defended the SIR project as having "explored a whole new technology" adaptable to land-based sodium systems for central station power, including development of fabrication techniques and components to handle high-temperature sodium. During its brief career, SIR-A, in addition to providing data for *Seawolf*, produced about 2-million kwh of electric power, 765,000 of it sold since last July to Niagara Mohawk Power Corp. at 3 mills/kwh.

Meanwhile, Rear Adm. H. G. Rickover declared the main obstacles in nuclear power development lay not with reactor design but with performance of conventional components (*excerpts p. 78*).

THREE NEW POWER PROJECTS

Three utility groups are planning nuclear power stations: **(1) American Gas & Electric Service Corp.** led by Philip Sporn, together with 11 private utilities in Ohio, Indiana, Kentucky, West Virginia, Maryland and Pennsylvania, plan a $15- to $31-million research program including construction of a 50-Mw (heat) prototype (perhaps without turbine) for 1961–62 completion, followed by a 200-Mw (electric) scale-up for service by 1964–65. Thee types are under consideration: a Babcock & Wilcox graphite-suspension unit with ceramic fuel elements; an NDA natural-U, liquid-metal-cooled, D$_2$O-moderated set; and a General Electric sodium graphite reactor with ceramic fuel elements. **(2) Pacific Power & Light of Portland, Ore.,** has bought 14 sq. miles west of Hanford as a nuclear station site, is continuing to study nuclear economics jointly with Washington Water Power, Portland General Electric, and Montana Power Companies. **(3) Pacific Gas & Electric,** already in on a 3-Mw GE pilot plant, intends alone or in partnership with other California utilities to propose a large, advanced pressurized water reactor in AEC's third round. It has already obtained preliminary estimates from GE and Westinghouse.

ARGONNE'S SEVENTEEN

CP-1 (Chicago Pile 1), the first reactor ever built, with which Enrico Fermi proved under the stands at Stagg Field that a chain reaction could take place, is well known by that designation; so is CP-5, the present Argonne heavy water research reactor. Less well known is that the CP series has reached 17. Here is the list:

CP-2—the reconstructed Stagg Field reactor at Palas Park;
CP-3—the first heavyweight reactor;
CP-4—EBR-1;
CP-6—Savannah River Pu-production reactor design;
CP-7—EBWR;
CP-8—EBR-2;
CP-9—ALPR, Argonne Low-Power Reactor for the Army,
CP-10—an isotope-production reactor design, not built;
CP-11—Argonaut;
CP-12—Arbor (NU, Jan. '57, R8);
CP-13—"The Mighty Mouse," a 250-Mw high-flux research reactor;
CP-14—"The Hot Box," probably a graphite-moderated, Na-cooled engineering test reactor of very high flux;
CP-15—the "slow-fast" reactor (NU, Dec. '56, R7);
CP-16—a closed-cycle gas turbine system;
CP-17—a transient test facility.

CP-13 to -17 are study projects. There is also a ZPR series at Argonne of zero power reactors: ZPR-I was to prove the STR (*Nautilus*) design; ZPR-II, Savannah River; ZPR-III, fast reactor design; ZPR-IV, fast exponential; ZPR-V, slow-fast; ZPR-VI, fast critical; ZPR-VII, thermal test facility; ZPR-VIII, Thud (*see below*).

ARGONNE WORKING WITH A THUD

A THUD program—Thorium–Uranium–Deuterium—is underway at Argonne to determine the nuclear characteristics of ceramic-fueled reactors using cores fabricated from thoria-urania pellets. Exponential experiments are being carried out, and a zero power reactor will shortly be in operation with a view to replacing EBWR's present plate-type core with one of this type late this fall, when its light water moderator-coolant is replaced with heavy water.

ACF TO DESIGN CASE TEST REACTOR

ACF Industries has been selected by Case Institute of Technology to make preliminary designs by August of a high-flux engineering test reactor and other nuclear research facilities for an industrial nuclear center proposed for Cleveland (NU, Feb. '57, R12). Power of the MTR-type reactor has been upped to 15–20 Mw (heat) with 2×10^{14} flux; estimated cost of the center has risen to $7-million. Schenley Industries has joined the original five sponsors. One of the five, the Austin Co. of Cleveland, will be architect-engineer for the center. Several 100-acre sites near Cleveland are under consideration.

ADVANCED ETR DESIGN STARTED

With AEC's Engineering Test Reactor not yet critical, Internuclear Co. of Clayton, Mo., has already completed for AEC as preliminary design study of an advanced engineering test reactor with a thermal neutron flux some 10× greater than the level attainable in the more advanced test reactors now being built.

NEW IDAHO CONSTRUCTION

Paul Hardeman Inc. of Los Angeles was apparently low bidder at $3,392,000 to build the Expended Core Facility (NU, Feb. '57, R10) at the NRTS naval reactor installation. The only other bid was $120,000 higher. . . . Arrington Construction Co. of Idaho Falls was apparent low bidder at $398,635 to build a radioactive waste disposal system at the NRTS naval reactor facility.

Report from Poland

Portrait of a Soviet-bloc Country's Nuclear Effort: Physics Research Emphasized, Merchant A-Ships Planned

WARSAW

Nuclear energy work is to Poland both a very old and a very new thing: old in that Marie Sklodowska-Curie was, in a sense, the first worker in the field; new in that it was not until 1955 that development of atomic energy got under way on a broad front and with a sense of urgency.

For until 1954 nuclear research and the application of nuclear energy had not been regarded in Poland as matters of urgent national importance. True, Andrzej Soltan had created a nuclear research group in the Experimental Institute of Physics that had been established at Warsaw University before the war under the direction of Stefan Pienkowski; its postwar work had been supported by formation of the Institute of Theoretical Physics under Leopold Infeld and Wojciech Rubinowicz. In 1953 an Institute of Physics of the Polish Academy of Science had been established, and here it was that that year Jan Danysz and Jerzy Pniewski discovered a new type of excitation of the nucleus—the bound hyperon.

Nevertheless a feeling prevailed that Poland was not sufficiently well equipped to pursue such ambitious goals, and that other tasks such as that of industrialization were of greater urgency. Up to that time nuclear scientists in Poland had available only a 1-Mev accelerator of the Greinacher type in Warsaw.

In 1954 preparatory work began under Bronislaw Buras toward construction of a Polish reactor of the graphite-moderated natural uranium type.

Kickoff in 1955

But it was in 1955 that work in nucleonics began to accelerate. Two main factors were responsible. First, on Jan. 17, 1955, the Soviet Union announced that five countries from which it had been for some time receiving atomic materials—China, Czechoslovakia, East Germany, Poland and Rumania—would be granted scientific and technical assistance that would enable them for the first time seriously to enter the nuclear field; aid was to include a research reactor, a cyclotron, radioisotopes and facilities for training scientists and technicians at establishments in the USSR. Second was the Geneva conference in August, which served as a further impetus to expansion of the atomic energy program, and drew public interest to it.

The spirit and enthusiasm generated by the Geneva meeting, and the promise of equipment, wrought a transformation in the position and tempo of nuclear science in Poland, and resulted in a number of new organizations—both governmental and academic—being created to carry out this development.

New Organization

On the governmental level, the post of Government Plenipotentiary for the Peaceful Uses of Atomic Energy was created—Wilhelm Billig is the first occupant—to draw up long-term development plans for the country and to coordinate the work of the various government departments. The Plenipotentiary is advised by a State Council on the Peaceful Uses of Atomic Energy. A Committee on the Peaceful Uses of Atomic Energy, attached to the Præsidium of the Academy, was also established under Prof. Infeld to plan and coordinate nuclear research, to help organize training, and to publish the new quarterly journal *Nukleonika*.

On the academic side, a new Institute for Nuclear Research under Prof. Soltan was set up at the Polish Academy of Sciences; it is now the main center of Poland's work in the field. It is responsible for large-scale research on reactor physics and technology, large-scale isotope production, nuclear instrument design, research on biological effect of radiation, and some medical work. The Institute is composed of two main centers: the two nuclear research centers of Warsaw and Cracow.

Warsaw. The Central Polish Nuclear Research Establishment at Warsaw is the successor to research efforts of two laboratories in the capital: the first under Prof. Soltan, the second under Prof. Buras. It has just completed a 4-Mev Van de Graaff, the first postwar all-Polish built accelerator. A new home for this "little Brookhaven" is being built at Swierk near Warsaw, where construction started in April 1956 and the first labs are to be completed this year. Here is being erected the Soviet-furnished research reactor. This will be a light-water-moderated and -cooled, well-type thermal unit operating at a power level of 2-Mw on 10% enriched uranium fuel, to provide an average thermal neutron flux of 10^{13}—essentially the same reactor Russia is building for a number of East European countries (see sketch, NU, April '56, 19). It will be used for experimental work in nuclear physics, chemistry and biology. Construction is well advanced, and target date for start of operation is September 1957.

At Swierk also, a group under Juliusz Keller has begun construction of a 10-Mev linear accelerator, for completion in 1958. This machine, which will operate independently at first, may later be hitched to a larger accelerator now contemplated.

Cracow. The Cracow Nuclear Research Establishment, headed by Henryk Niewodniczanski, specializes in nuclear physics exclusively. It is the successor to the Cracow Nuclear Physics Laboratory of the Academy of Sciences' Physics Institute. The Establishment has been working particularly in the field of photonuclear reactions, and has equipped itself with a large installation for magnetic nuclear resonance, a large spectrometer based on scintillation counters, and an 800-kev Van de Graaff completed last June, and a 3.5-Mev cyclotron designed and completed last December by a Polish team.

Like its sister establishment at Warsaw, the center is getting a new home, at Bronovice near Cracow. Construction began late in 1955 on the buildings, including engineering, electrotechnical and radiation labs, and completion is scheduled by year's end. Here is being installed the 12.5-Mev cyclotron from Russia, parts for which are now being delivered, and which is scheduled to start operating late this year.

Fuel Resources

Some uranium and thorium have been found in Polish phosphate and granite deposits, and exploitation is now beginning. However, Minister Billig announced last December that "Poland lacks the necessary knowledge and funds to process uranium ore successfully and therefore has agreed to sell to the Soviet Union all Polish uranium o[illegible]mined." Prices to be paid by the USSR for ore or concentrates will be higher than prevailing world market rates, he said. (At the same time, he disclosed that "negotiations are under way in Moscow aimed at a drastic reduction of prices charged

by the USSR for the equipment being installed at present in the nuclear centers of Warsaw and Cracow"—the research reactor and the big cyclotron.)

Domestic production of metallic uranium is thus quite a few years away, and any early nuclear power program would require importation of the fuel.

Power: To Be or Not To Be

This is the question that has been under discussion for the past year, by scientists, economists and power engineers among others. The problem is not an acute one—yet, thanks to Poland's huge deposits of both hard and brown coal. On the other hand, foreign demand for Polish coal might make it beneficial to produce a certain amount of power and heat from nuclear fuels, thus releasing large quantities of coal for export. Under these conditions—taking into account the favorable price of export coal—nuclear power might already be economic.

Looking ahead two decades, however, nuclear power becomes a must. Poland, which produced 9-billion kwh in 1950 and 18-billion in 1955, is expected to need 30-billion in 1960—but 140-billion by 1975. That rate of consumption can no longer be satisfied using coal alone.

In spring 1956, a team of physicists and power engineers was set up at the Nuclear Research Institute to study plans for a possible atomic station; in May a conference on the subject was held, but no positive recommendation issued from it. "The plan for construction of a nuclear power plant has been discussed," said Minister Billig in an interview, "but Poland is withholding final decision until after 1960, since cadres are lacking, industry is unprepared, and no clear decision on the best plant type can be formed at this early time." Other reasons may have been: capital investment for coal-fired plants is still considerably less than for nuclear; and a Polish nuclear station could be started now for 1960 completion only if Russian help were available—and the Soviet, having made promises of power plants to Czechoslovakia, East Germany, Hungary and China, and with a heavy program of its own, may not be in a position to offer further assistance.

At any rate, published directives for the 1956–60 five-year plan call on the country's scientists only "to carry out research into methods of gaining electric power by means of nuclear reactors" and "to master the technology and prepare the production of metallic uranium and of chemical materials required for this."

. . . and Propulsion

The same directives, however, call for research on "application of atomic energy to ship propulsion." Poland is the largest shipbuilder of the Soviet bloc next to the USSR itself; by 1960 it will be launching 200,000 tons/yr. Biggest ships built so far are 10,000-ton motor freighters for Far Eastern service, but a series of 18,000-ton tankers is planned. So Poland appears to be the likely country to specialize

in nuclear propulsion for merchant ships—which in the Soviet is already held to be more economic than conventional power. The Nuclear Research Institute jointly with the Maritime Institute and the Central Bureau of Ship Construction are already studying the economics of the matter.

Training

Most important problem facing the Polish nuclear effort is that of training scientific and technical personnel—although there are 400 scientists and technicians working at the Nuclear Research Institute, the demand for more trained personnel is unslaked—and a comprehensive plan is being worked out to train undergraduates in nuclear engineering. This is to be done at the universities and institutes of technology: the two research establishments will limit themselves to sponsoring short courses in radioisotope utilization and will otherwise not serve as training institutions. Nuclear physics will be taught at the Universities of Warsaw and Cracow, nuclear chemistry at the former, and nuclear power engineering at the Institutes of Technology of Warsaw and Wroclaw.

Some Polish scientists and technicians are receiving training at Soviet nuclear establishments, in reactor operation as well as theory and design. Poland is a member of the Joint Nuclear Research Institute at Dubna near Moscow (NU, Nov. '56, R11)—in fact Jan Danysz is one of the deputy directors—and this gives the country access to some of the largest, most advanced research equipment. There are also plans to send Polish nuclear scientists to the U. S., England and France for training, and to invite British, French, Soviet and U. S. scientists to Poland. In addition to *Nukleonika*, three other scientific journals in physics and nuclear science are published; two of them have editions in Western languages.

(Based on an article written especially for NUCLEONICS by Prof. Buras, a high ranking scientist in the Polish atomic energy program, this report incorporates also material from numerous other sources.)

Norway Gets Bilateral, Unclassified, for Power

First agreement for cooperation to be completed this year, a power bilateral with Norway, has just fulfilled the required 30-day period before the Joint Committee on Atomic Energy. It is the first of the new power agreements that provide for transfer of 500 kg U^{235} to fuel a power reactor but require no transfer of classified information; under the new declassification guide, power reactors can now be designed and built using only unclassified data. The U^{235} may be contained at enrichments up to 20% except for 6 kg that may be contained at 90% for use in a materials testing reactor. First use of enriched U imported from the U. S. will be in the Halden process-steam reactor. This, the second JENER reactor (NU, March '57, R10), will be ready for test operation this year. The 20-Mw (heat) unit will furnish 20% of the steam requirements of the Saugsbrugsforeningen wood processing mill, running between 80 and 100 tons/hr. Heavy water producer Norsk Hydro will donate half the 14-ton inventory of D_2O moderator. For safety's sake, the reactor is located 150 ft inside Høkefjell mountain, with a 180-ft ceiling of solid rock.

World News

New Power Plan in Japan

Japan's nine regional utilities have adopted a new nuclear power plan calling for 960-Mw capacity by 1965 and 9,910-Mw by 1975; they believe the project can be put on a paying basis by fiscal '61 or '62. By this time, it's said, cost of nuclear fuel would be down to 4 yen/kwh (10.4 mills), construction costs down to 23 yen/kwh (6¢), and both subject to further reductions. The Japan Atomic Energy Research Institute is already drawing up plans for establishment of a chemical reprocessing and waste disposal plant; construction of a first-stage one will begin in fiscal '58, at the nuclear research complex at Tokai north of Tokyo where the first research reactor built by Atomics International is nearing completion.

Nuclear Power for Ulster

Britain's new, expanded atomic power program includes provision for a 150-Mw Calder-type station for Northern Ireland, to come on the line in 1963 or 1964. To cost $70-million, the station will provide Ulster with 1/5th its total generating capacity. Unlike the nuclear stations in England and Scotland, this one will be inland rather than on the coast; a number of sites are under survey.

Soviet Still Only Talking Egyptian Aid

Egypt's official news agency announced four Soviet nuclear physicists would be in Cairo "within the next few weeks" to study requirements of Egypt's long-planned nuclear research center, and the government daily *Al-Gumhouriya* said Egypt's AEC expected arrival in the next few days of the first "batch of atomic equipment" it had ordered in the U.S.S.R. last year. A year ago the Russians announced they were offering Egypt a complete nuclear physics lab and technicians to help set it up (NU, May '56, 23); ever since, this has been a constant Soviet propaganda theme in the area, but until now there has been no sign of materialization of the offer.

Acceleration in Italy

Italian nuclear activity was in high gear last month:

- Sorin, the subsidiary set up last summer by Fiat and Montecatini for industrial exploitation of atomic energy (NU, Sept. '56, R6), has selected sites for a research and isotope production center where it will install a high-power pool reactor, and for a 100–150-Mw nuclear power station between Milan and Turin, perhaps at Chivasso. These are of course in addition to the first research reactor, a CP-5 ACF is building for the National Committee for Nuclear Research at Ispra, and the first power reactor, a 134-Mw Yankee-type Westinghouse will supply for Edisonvolta, the Milan utility.
- Two other groups are planning power stations, both in South Italy: Società Elettronucleare Italiana, a syndicate of utilities; and a government-financed group sponsored by the two State corporations E.N.I. and I.R.I.
- The Sicilian Regional Assembly is pushing plans for establishment of a nuclear physics center there.
- Radioactive ores have been found near Cuneo south of Turin, and Fiat has applied for prospecting rights.
- A Westinghouse official in Rome declared the Edisonvolta plant would produce power at significantly lower cost than PWR's announced 52-mill figure; he said loading would be 28,800 kg of U enriched to 3.7%.
- CAAI—Centro Aeronautico & Atomico Italiano—has been founded as a private, nonprofit firm to promote progress in both aircraft and nuclear energy fields; in the latter category, it will seek to aid Italian nuclear physics research, construction of power and propulsion reactors, and isotope application.

Canada May Export U to Germany

West Germany is negotiating with Canada for importation of 100 tons/yr raw U ore, and is offering in exchange to build a U-melting plant in Canada.

Another Big U Operation in Australia

South Australia's government is conducting negotiations with an unnamed foreign firm to operate a major open-cut U-mine at Crockers Well, north of Radium Hill, South Australia. Both high- and low-grade ores will be mined; a concentration plant will be built at Crockers Well and a mill at Port Pirie.

UNESCO Isotope Parley Set for September

An international conference on radioisotopes in scientific research will be sponsored by UNESCO Sept. 16–27 in Paris, as part of a plan to ease the workload of the second Geneva conference on peaceful uses of atomic energy in 1958 and permit it to concentrate on nuclear power. The Paris meeting will cover uses of radioisotopes in the physical and biological sciences, new developments in measuring techniques and isotope production; it's aimed at providing a broad exchange of information; 1,000 are expected to attend. Other conferences may be scheduled early in 1958 on radiation chemistry, genetics and medical applications.

Uranium Found in Central Asia

Dmitri Scherbakov of the Soviet Academy of Sciences reports discovery of uranium in Kazakhstan and other areas of Soviet central Asia.

Post-Revolt Delays in Hungary

The Kádár régime claims that uranium mining at Pécs and Battonya, halted since Oct. 25, will be resumed this summer after conclusion of current Soviet-Hungarian negotiations and "after surface damages are cleared up." Plans to commission the Soviet-supplied 2-Mw research reactor this year are now not exepcted to be fulfilled; head physicist Géza Számosi and a number of scientists, engineers and technicians have left the country. Construction is continuing at slower pace. A 100-Mw power reactor project has been started, with the aim of beginning construction in 1959 or 1960 for completion in four years.

Belgian Atomic Syndicate Reorganizes

S.E.E.N.—Syndicate d'Etudes de l'Energie Nucléaire, the syndicate of 20 big private Belgian industrial companies that has been taking the lead in working toward nuclear power in Belgium—is phasing itself out of existence. A new operating combine, Société Belgonucléaire, has been formed by SEEN members and eight additional firms; SEEN will be closed out within three years when it has spent its funds. President Herman Robiliart and managing director Jean Van der Spek of SEEN retain the same posts in Belgonucléaire. Functions of the new company will be: conception, design and construction of reactors; fabrication of fuel elements; chemical reprocessing and application of radioisotopes. Initial capitalization is $200,000.

News in Brief

Price Sets Price on 95% Enriched U

When AEC published a price list on enriched uranium (table, NU, Dec. '56, R2), it gave figures on progressive stages of enrichment up to 90%. Last month Harold Price, AEC director of Civilian Application, announced the cost of a kg of U^{235} contained at 95% enrichment: $16,258, higher by $897 than a kg of U^{235} contained at 90%. Prices are for U in the form of UF_6. Price also announced that any enriched U distributed in the civilian program is unclassified: previous classification of material containing in excess of 90% U^{235} is no longer in effect.

Big Program for Clemson

Clemson (S. C.) College is embarking on educational and research programs in nuclear science that will cost $8.5-million. This amount will include purchase of a large research reactor and a building to house it, an isotope laboratory, research and instructional labs and teaching and research equipment. The facility will be designed to meet industrial needs in South Carolina as well as to train nuclear engineers.

Enter the Nuclear Weaponsman

The Navy plans to establish a new rating: Nuclear Weaponsman. After enlistment as "Nuclear Field Seaman Recruits," specialists in the new field will get training in nuclear power plants as well as A- and H-bombs, nuclear mines and nuclear warheaded guided missiles.

Zirconium for Columbia-Southern Chemical

Columbia-Southern Chemical Corp., itself a wholly-owned subsidiary of Pittsburgh Plate Glass Co., has become an equal stockholder with National Research Corp. in NRC Metals Corp., until now a wholly-owned subsidiary of National Research. The two firms will employ NRC Metals "as a vehicle for their activities relating to the manufacture and sale of Zr and Hf metals and chemicals." NRC Metals, which has an AEC contract to supply 3.5-million lb Zr and Hf, is now building near Pensacola the first fully-integrated facility to produce high-purity Zr and Hf sponge from Florida zircon sand. Columbia-Southern has specialized in production of chlorine and alkalies.

Kaman Organizes Division

Kaman Aircraft Corp. of Bloomfield, Conn., is forming a nuclear division to be located in Albuquerque, N. M., for systems analysis and research in nuclear ordnance and propulsion. Heading it as vice president and general manager is Kenneth W. Erickson, former chief of experimental weapons research at Sandia Corp.

Thermal Diffusion for Zr?

Tennessee U. has been given a $25,000 contract by Union Carbide Nuclear Co. of Oak Ridge to study and test the feasibility of using thermal diffusion process to extract zirconium. The process is based on the principle that circulating a liquid between hot and cold walls will tend to pull apart hard-to-separate products within the liquid; it has been used in industry in work with solvents, dyes and pharmaceuticals, but heretofore only to separate non-metallic substances. Key component of the proposed Zr process is a new horizontal thermal-diffusion column, conceived originally as a tool for separating organics; standard thermal diffusion equipment is vertical. Tennessee U. engineers will first try the new column to separate common salts, then salt mixtures obtained from metallic ores. The one-year contract covers only the first phase.

More Space for B&W

Babcock & Wilcox is expanding its research center at Alliance, Ohio, with building of a 15,700 ft^2 edifice east of the present office building for growing nuclear engineering research activities, and addition of a two-bay, 1,120 ft^2 structure to an existing building, to house product development personnel. Ground is to be broken this month.

Rochester Physics Conference Growing

What is described as the largest international gathering of nuclear physicists ever held will meet April 15–19 for the seventh annual Rochester Conference on High Energy Physics at Rochester (N. Y.) U. Attendance is by invitation only; 300 are expected, 85 of them from 25 foreign countries including Russia.

Nuclear Research Center for Socony Mobil

The 315-acre Stony Brook Farm, Hopewell township, near Princeton, N. J., has been bought by Socony Mobil Oil Co. for construction of a nuclear research center to study application of radiation to petroleum technology. It will be operated as a subdivision of Socony Mobil Research & Development Lab at Paulsboro, N. J.

Kaiser Moving Ahead on FIR

Kaiser Engineers has signed a $125,000 contract with AEC to do research on the physical and corrosion properties of indium sulfate leading to in-pile loop tests on this little-known substance which will be the irradiation medium in the Food Irradiation Reactor (NU, Jan. '57, R3). The tests are to be completed by end of July; indications are that as soon as feasibility of using indium sulfate is established, Kaiser will be awarded the FIR design and construction contract.

WBNS Power Increased

Atomics International has moved its Water Boiler Neutron Source, working at Downey since 1952, to Santa Susana and upped its power from 5 to 2,000 watts.

Squibb Enters Isotope Production

E. R. Squibb & Sons has built a $200,000 plant at New Brunswick, N. J., designed specifically for production of radioactive gold, phosphorus, and iodine for medical diagnosis and therapy. Production is expected to start this spring.

Allied Chemical Selects Site

Six hundred acres at Metropolis, Ill., on the Ohio river, will be the site of a multimillion uranium hexafluoride plant Allied Chemical & Dye Corp. is building (NU, Dec. '56, R2). This will be the first privately-owned plant producing "hex" for AEC.

Sylvania-Corning Now Official

Formal establishment of Sylvania-Corning Nuclear Co. was accomplished last month by Sylvania Electric Products and Corning Glass Works (NU, Dec. '56, R6; March '57, 112). The new firm will maintain headquarters in Bayside, L. I., at the present site of Sylvania's atomic energy division.

Yukawa Resigns from Japanese AEC

Japan's Nobel Prize-winning physicist, Hideki Yukawa, resigned from his country's AEC last month on the ground of illness. He had sought to resign last summer.

RADIATION

no matter what its source

can **BEST** be analyzed

using the unmatched

SPEED

PRECISION

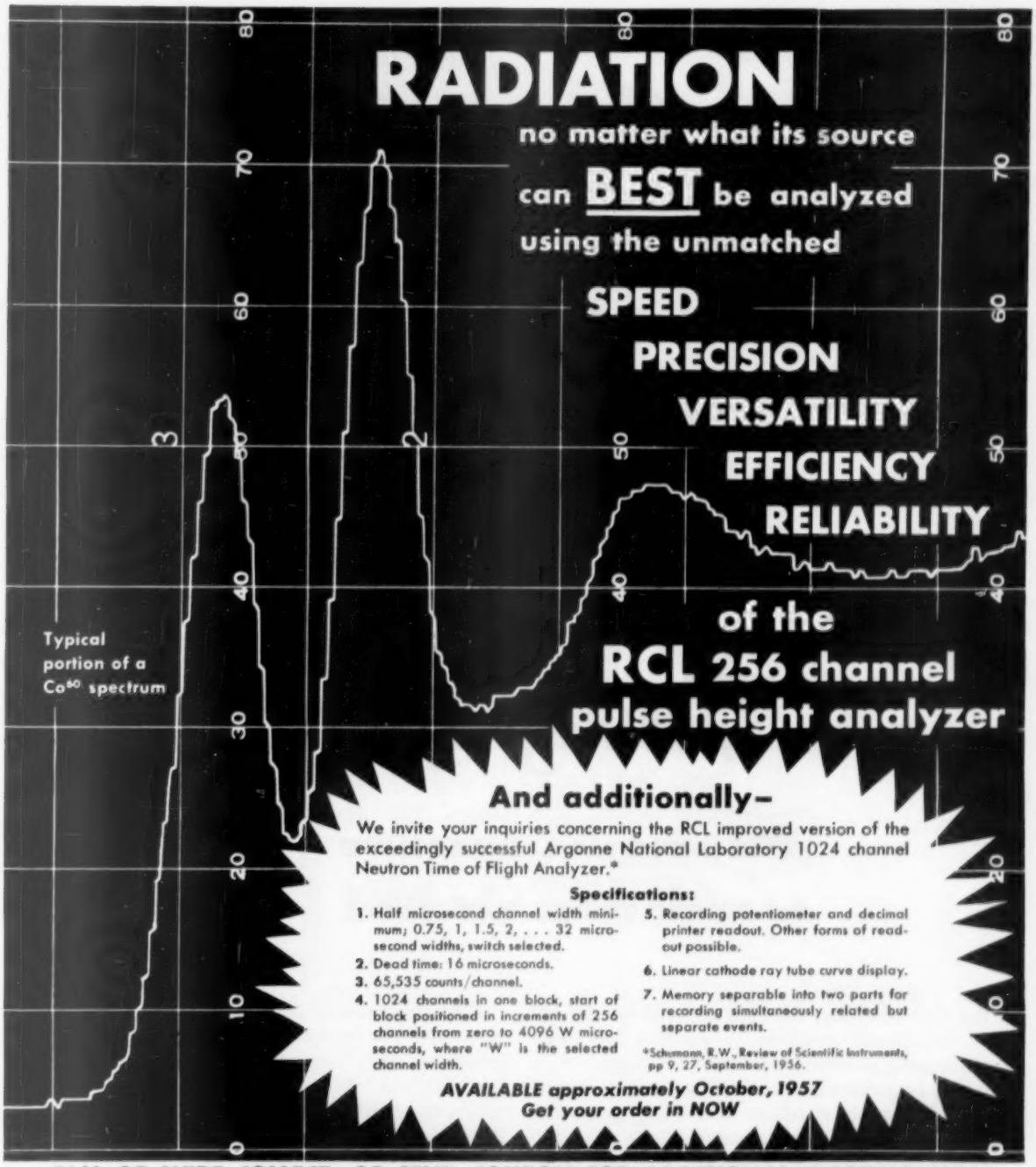
VERSATILITY

EFFICIENCY

RELIABILITY

of the

RCL 256 channel pulse height analyzer



And additionally–

We invite your inquiries concerning the RCL improved version of the exceedingly successful Argonne National Laboratory 1024 channel Neutron Time of Flight Analyzer.*

Specifications:

1. Half microsecond channel width minimum; 0.75, 1, 1.5, 2, . . . 32 microsecond widths, switch selected.
2. Dead time: 16 microseconds.
3. 65,535 counts/channel.
4. 1024 channels in one block, start of block positioned in increments of 256 channels from zero to 4096 W microseconds, where "W" is the selected channel width.
5. Recording potentiometer and decimal printer readout. Other forms of readout possible.
6. Linear cathode ray tube curve display.
7. Memory separable into two parts for recording simultaneously related but separate events.

*Schumann, R.W., Review of Scientific Instruments, pp 9, 27, September, 1956.

AVAILABLE approximately October, 1957

Get your order in NOW

CALL OR WIRE COLLECT, OR SEND COUPON FOR ADDITIONAL INFORMATION

Radiation Counter Laboratories, Inc.

NUCLEONIC PARK, SKOKIE, ILLINOIS

Radiation Counter Laboratories, Inc., Dept. 147
Nucleonic Park, Skokie, Illinois

Gentlemen,
Please send me additional information about the:

- ☐ RCL improved 1024 channel Neutron Time of Flight Analyzer.
- ☐ RCL 256 channel Analyzer.
- ☐ RCL 1024 channel two Dimensional Coincidence Analyzer.

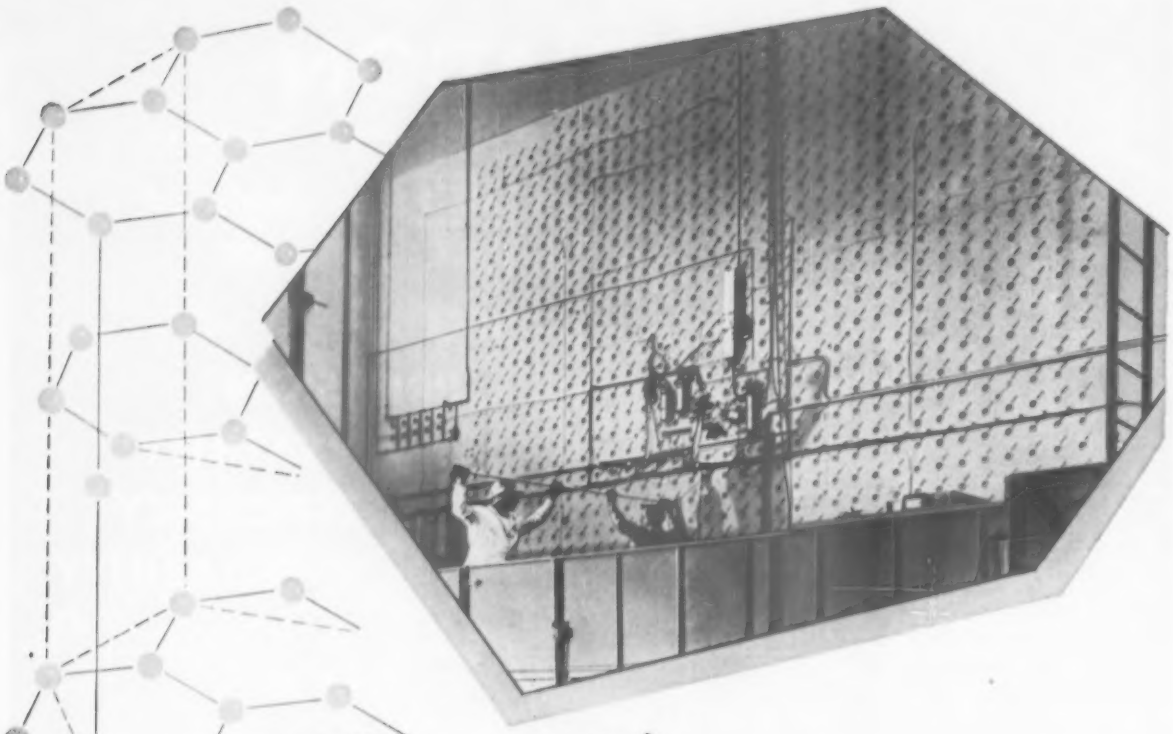
Name _____

Title _____

Firm _____

Address _____

City, State _____



Thoroughly job-proven

NATIONAL GRAPHITE
TRADE MARK

for atomic energy applications

MODERATOR
REFLECTOR
SHIELDING
THERMAL COLUMN
MOLDS AND CRUCIBLES

For dependability, economy and safety, the use of "National" graphite in reactors has been thoroughly proven and accepted. "National" high purity graphite was specified for the first reactors built because of excellent moderating properties and low neutron capture cross section. Its additional properties assure an ever widening range of applications in the nuclear industry.

Most important of these is graphite's ability to withstand the increasingly higher reactor temperatures. Also, it is safe to handle . . . is easily machined and fabricated . . . possesses outstanding corrosion resistance and embodies the high purity demanded by many atomic energy applications.

A product of the largest and most experienced producer of fabricated carbon and graphite, "National" graphite is readily available in many different grades, shapes and dimensions for specific atomic energy requirements.

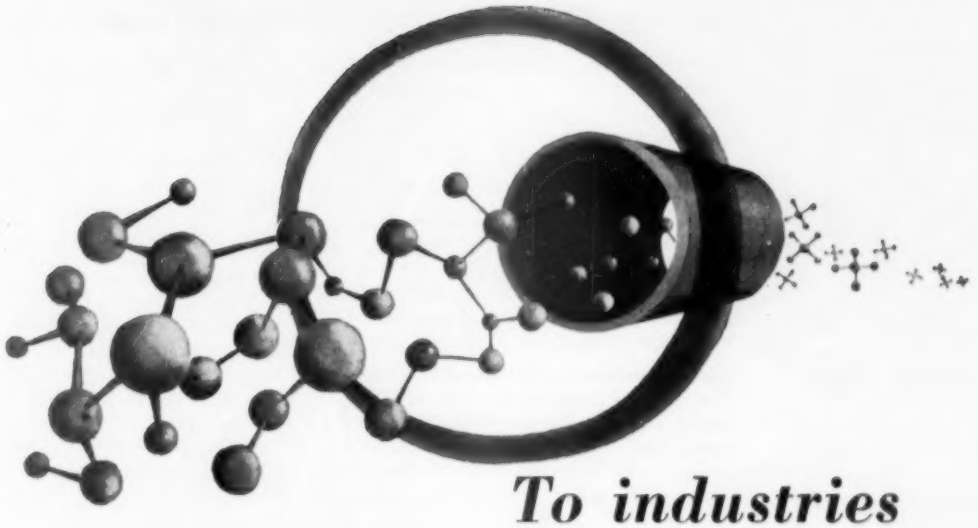
• • •

These important technical publications are yours for the asking. Just write on your company letterhead for your copy of "The Production and Properties of Graphite for Reactors" and for Catalog Section S-4905, "National Graphite for Atomic Energy Applications."

The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY • **A Division of Union Carbide and Carbon Corporation** • ***30 East 42nd Street, New York 17, N. Y.***

Sales Offices: Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. *In Canada:* Union Carbide Canada Limited, Toronto



To industries interested in

GAMMA RADIATION

for Chemical Processing • Sterilization
Polymerization and cross-linking
Vulcanization • Cracking and other
effects of radiation on materials

WE OFFER:

- radioactive Cobalt 60 in kilocurie quantities
- a self-contained gamma irradiation unit
- a gamma irradiation service
- a design and consulting service and custom-built equipment

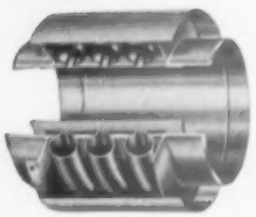
FOR MORE INFORMATION WRITE TO

ATOMIC ENERGY OF CANADA LIMITED

COMMERCIAL PRODUCTS DIVISION

P.O. Box 93 Ottawa, Canada

NEW ZALLEA HyPTor* TOROIDAL EXPANSION JOINT



HyPTor corrugations have a circular or toroidal cross section which provides a lower operating stress at any given pressure than any other corrugation shape.

For unequalled endurance at pressure and temperature extremes

This unique toroidal expansion joint with thin-walled bellows is setting new performance and durability records in high pressure, high temperature service. It was developed to meet the severest operating conditions without sacrificing long life.

Minimum stress at high pressures is one advantage of the Zallea HyPTor. This is due to the thin-walled bellows and toroidal corrugations. Thin walls develop lowest flexing stress. The toroidal cross section assures lower operating stress at any pressure.

Superior performance at high temperatures. The toroidal corrugation of the HyPTor makes it suitable for use at high temperatures. Also, the HyPTor is hydraulically formed and free from circumferential welds which would act as stress raisers.

Longer life on the job. The ability of the HyPTor to absorb punishment without ill effects has been proved in service. A number of HyPTor Expansion Joints designed for 700 psi working pressure, were installed in liquid oxygen service in 1948. They are still operating . . . at pressures up to 2300 psi.

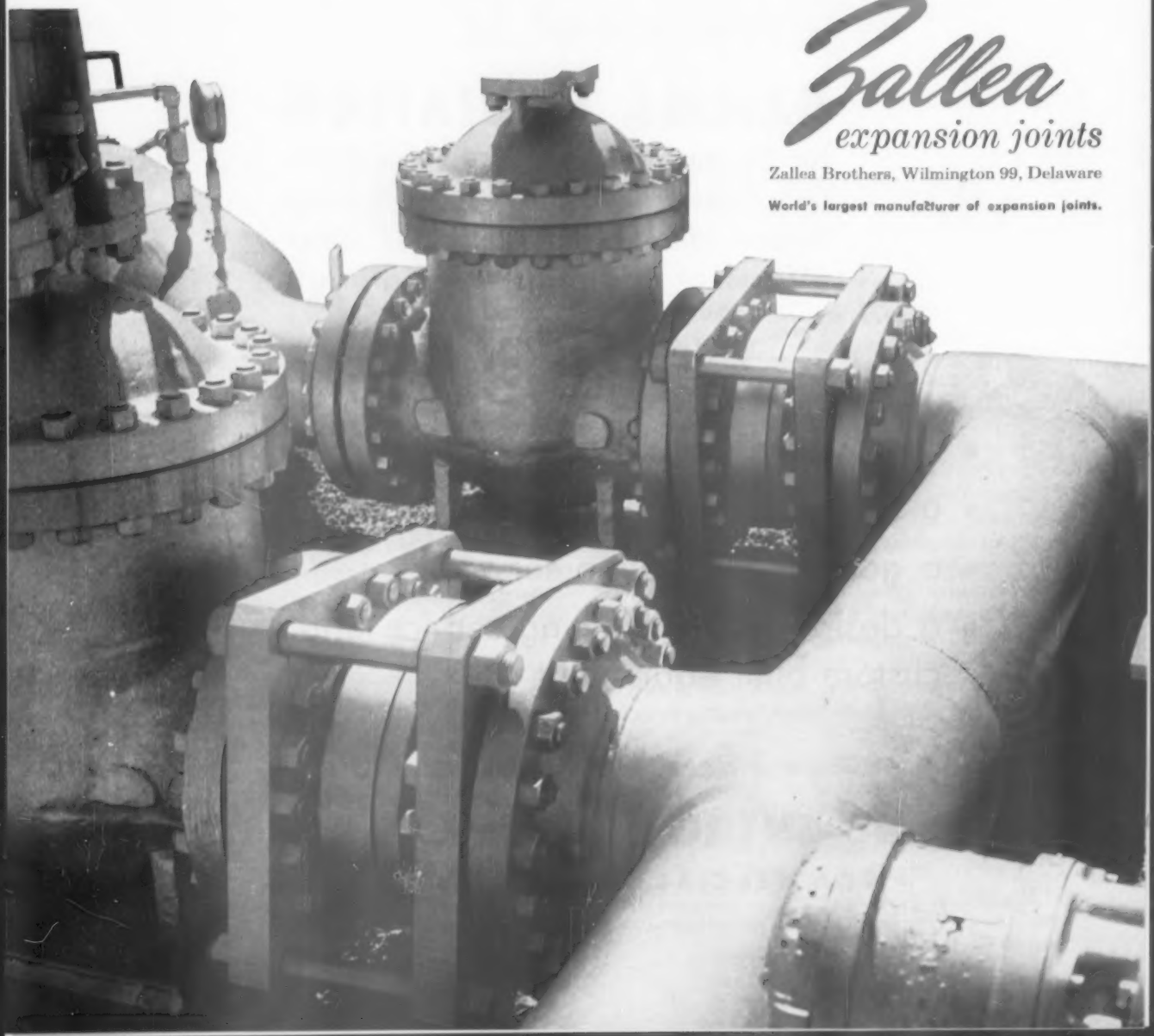
Get the complete story of the new Zallea HyPTor Expansion Joints. Our new 72-page Expansion Joint Manual gives full details—plus worthwhile information on basic types, design and installation data, expansion joint selection and recommended specifications. Write on your Company letterhead, for your free copy of Catalog 56, Zallea Brothers, 879 Locust Street, Wilmington 99, Delaware.

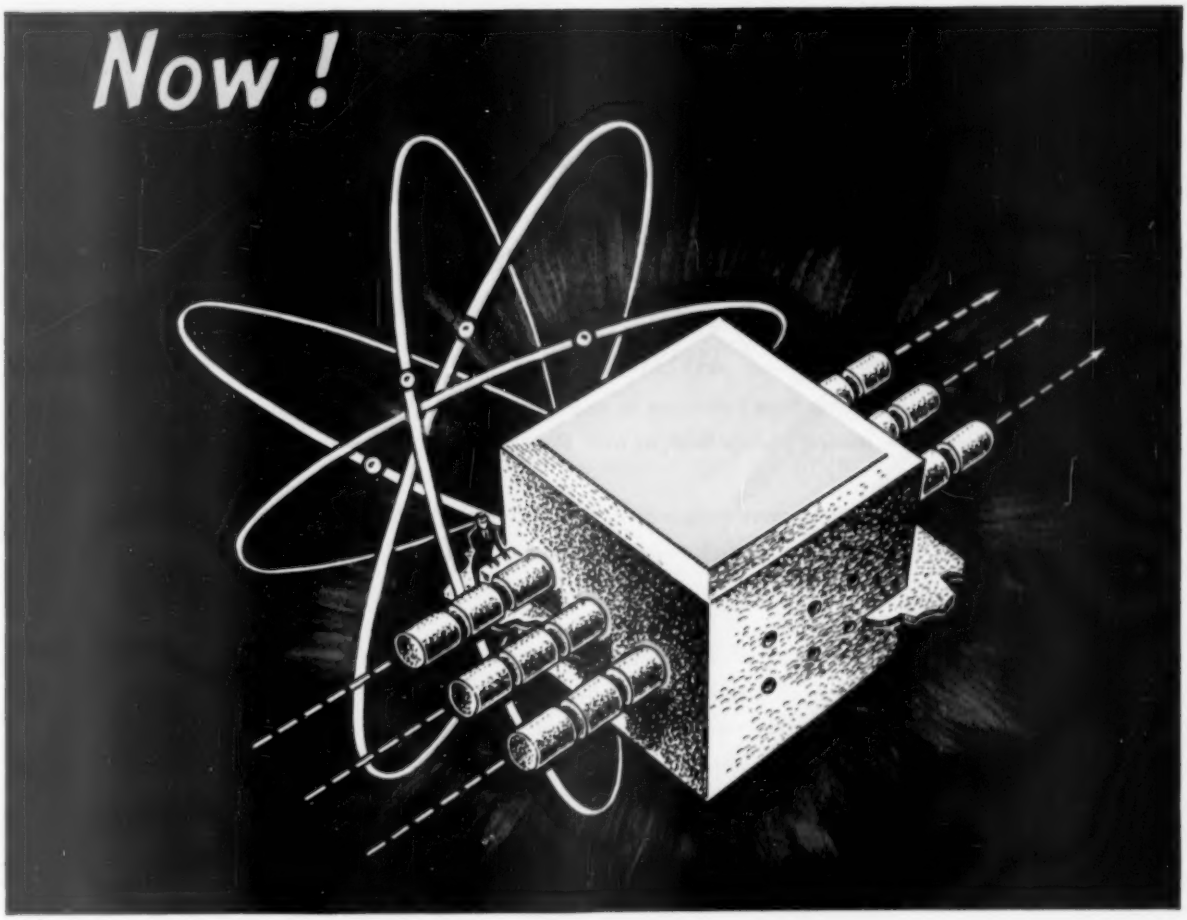
*Patented

Zallea
expansion joints

Zallea Brothers, Wilmington 99, Delaware

World's largest manufacturer of expansion joints.





Norton ceramic fuel elements

Separate facility now producing ceramic fuel elements and various reactor components

To meet the demand for more-economical, more-efficient reactor fuels, the trend is towards ceramic types — because of their greater resistance to corrosion and radiation, the ease with which they can be reprocessed, and their ability to operate at higher temperatures. Norton Company's long experience in the development of high-purity ceramics has now led to the commercial production of ceramic fuel elements.

Take Advantage of Norton Assistance in bringing special nuclear materials into successful use in the development of nuclear power plants. In addition to the development and production of ceramic reactor components, Norton experience includes highly specialized refractories for missile, metallurgy, chemical, and furnace applications. These top-performing Norton refractory ℞'s — *engineered and prescribed* for the widest range of uses — are of increasing interest to nuclear engineers. They include alumina, silicon carbide, thoria, urania, zirconia, magnesia, dolomite, and numerous borides, carbides and nitrides — that have benefited nuclear as well as general industrial developments.

A special Norton Research and Development section, devoted to the development of precision ceramics and familiar with both nuclear and refractories development, co-operates whenever possible with industrial, government and academic research activities. Your progress may be speeded up by utilizing Norton co-operation and products. For further information write to NORTON COMPANY, Refractories Division, 653 New Bond Street, Worcester 6, Massachusetts.

NORTON
REFRACTORIES
Engineered... ℞ ...Prescribed

Making better products . . .
to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels
Grinding Machines • Refractories
BEHR-MANNING PRODUCTS: Coated Abrasives
Sharpening Stones • Behr-cat Tapes

On this subject:

HEAT EXCHANGERS FOR NUCLEAR SYSTEMS

. . . Ross speaks with experience

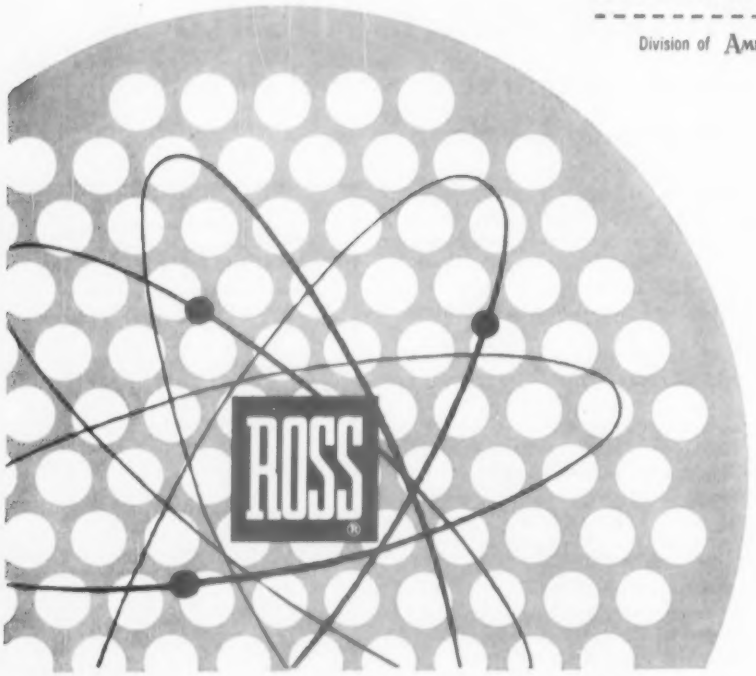
The initiative which Ross has taken in virtually every field of heat exchanger development applies to the nuclear energy field, as well. Ross engineers were early at work.

Starting with exchangers designed and fabricated for the Manhattan Project, and carrying on down right through to today, Ross has been steadily building its reputation in nucleonics' circles.

The readiness of Ross to perform engineering development; the possession of the necessary skills to work with specialized materials; the ability accumulated through experience to meet stringent specifications . . . these and others are points which Ross engineers would be pleased to discuss with you. Yes, Ross can speak with experience. Your inquiries are invited.

Ross Heat Exchanger Division of American-Standard, Buffalo 5, N. Y.
In Canada: American-Standard Products (Canada) Limited, Toronto 5, Ont.

ROSS HEAT EXCHANGER
Division of AMERICAN-Standard



and it costs no more!

Now, with the many accessories offered, the Central Research Manipulator lets you perform an even greater variety of intricate operations. All of these accessories are remotely interchangeable . . . each is the product of precision craftsmanship and exacting control of tolerances. The manipulator itself has that inherent "sense of feel" which is the result of continuous design improvement and rigid quality control throughout every phase of manufacture. Field maintenance is simplified by standardization and interchangeability of parts, yet each manipulator is "custom built" by skilled craftsmen with years of experience. Because of this individual attention the CRL Manipulator is easily adapted to your particular needs.

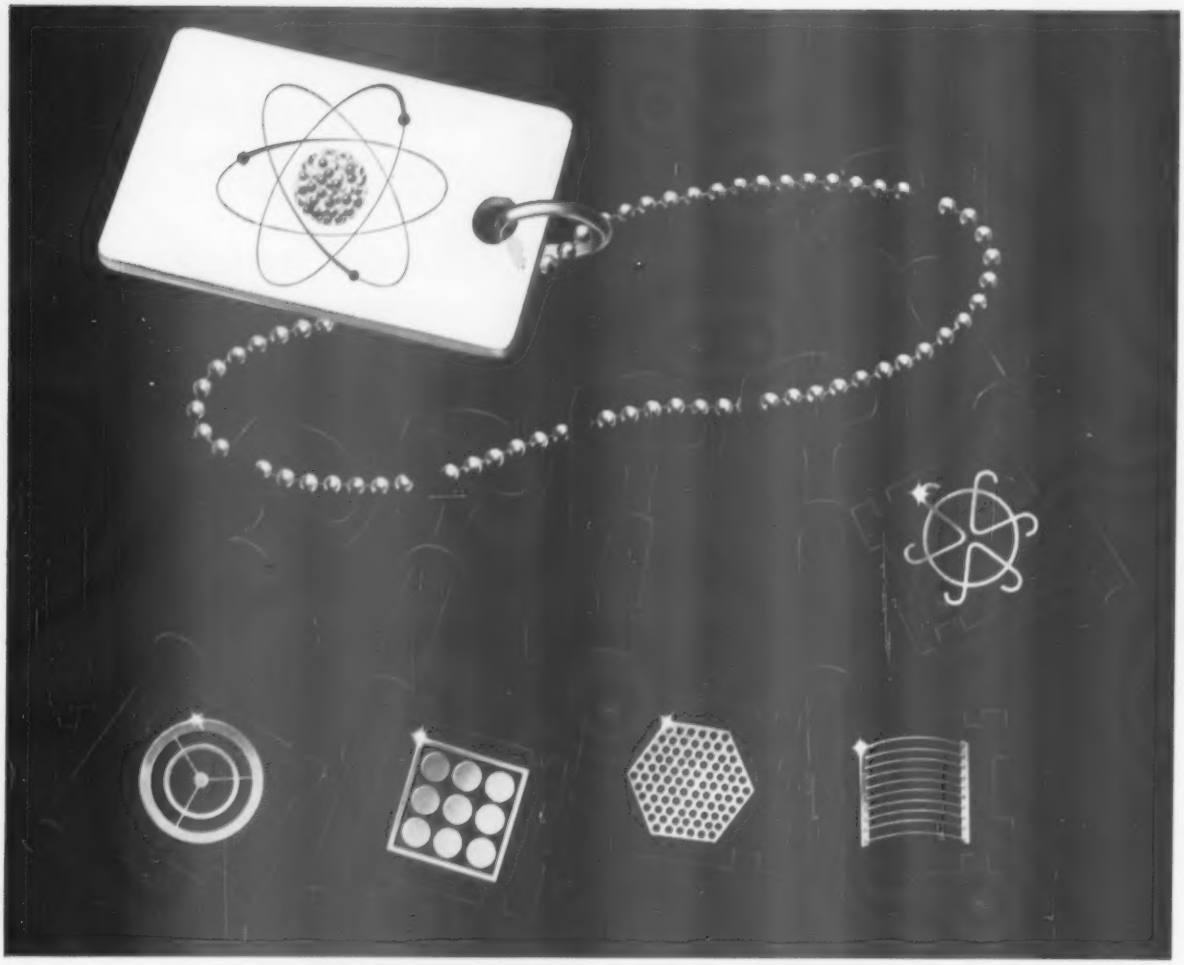
If you use—or plan to use—hazardous materials that require intricate handling, CRL Manipulators will speed up your production or research program. We will also be glad to advise you on the layout of hot cells and other research areas, to help you gain maximum benefit from your CRL Manipulator.

central research manipulators
from basic Argonne National Laboratory design

write today for complete information to:

Central Research
laboratories, inc.
Red Wing, Minnesota

Dept. 101



Which is the key to economical nuclear power?

In any reactor, economical power production depends a great deal upon the design, composition and construction of the fuel element itself. Shape, size, mechanical structure and degree of enrichment all play a part in the extraction of maximum energy with minimum fuel cost.

Sylvania was a pioneer in the development of efficient reactor fuel elements and practical reprocessing techniques. During more than eight years of successful experience in solving advanced technical problems in atomic energy, Sylvania has built up a unique and highly specialized research organization. Staffed with top-ranking scientists and engineers, working in well-equipped laboratories, Sylvania carries on a constant program of reactor fuel research in four basic fields: materials development, fabrication development, test methods development and prototype model production.

Particular stress is laid upon the development of test methods—both in and out of reactor. For only by means of satisfactory test methods can new designs and materials be evaluated. To this end, Sylvania has perfected a number of unique methods of reliable projective evaluation.

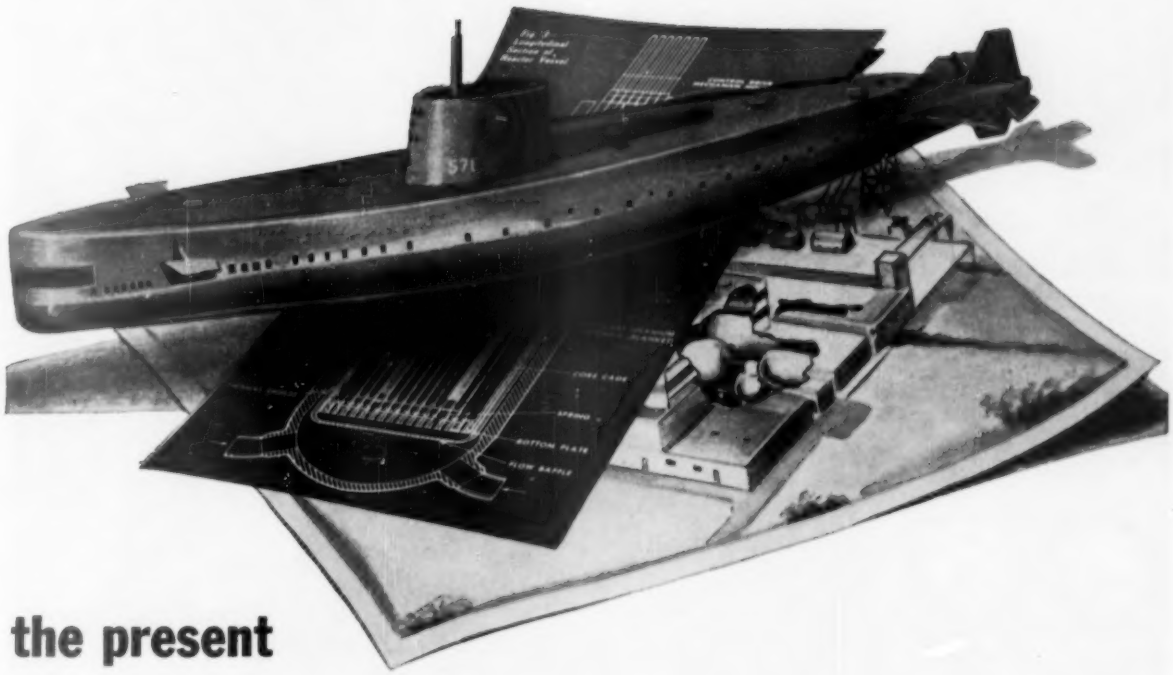
If you are wondering which type of element will prove most effective in your own reactor, we will be glad to make recommendations on the basis of our long and specialized experience in nuclear fuels. Write for a booklet on Sylvania Nuclear Fuel Elements.

SYLVANIA ELECTRIC PRODUCTS INC.
Atomic Energy Division, Bayside, New York
In Canada: Sylvania Electric (Canada) Ltd.,
Shell Tower Building, Montreal
Sylvania International Corporation,
22 Bahnhofstrasse, Coire, Switzerland.

SYLVANIA

ATOMIC ENERGY DIVISION

LIGHTING • RADIO ELECTRONICS TELEVISION • ATOMIC ENERGY



the present

and

YOUR FUTURE IN ATOMIC POWER

The USS *Nautilus* prototype was the first successful application of nuclear power. In 1957 the nation's first full-scale commercial generating plant at Shippingport will have its turbines powered by a Westinghouse reactor. Although the success of the nuclear reactor is a historical milestone, the application of nuclear power is still in the pioneering stages.

Much applied research remains to be done before the potentialities of nuclear energy can be utilized to the fullest extent. Opportunities for original work in a variety of fields present a creative environment for your professional growth.

At Bettis Plant, operated by Westinghouse for the Atomic Energy Commission, more nuclear power reactors are being designed and developed. Here scientists and engineers are continuing to investigate new areas for progress in all phases of reactor theory, design, and application.

If you are a physicist, mathematician, metallurgist, or a mechanical, chemical, or electrical engineer, interested in the challenging opportunities offered by the leader in the nuclear power industry, write for a descriptive brochure on the opportunities in your field. Be sure to specify your interests. Address: Mr. M. J. Downey, Westinghouse Bettis Plant, Dept. A-140, P. O. Box 1468, Pittsburgh 30, Pennsylvania.

BETTIS ATOMIC POWER DIVISION

Westinghouse

He "quarterbacked" L&N know-how into a finished control system for ETR

This project engineer coordinated the recently completed L&N control system for the 175,000-kw (heat) Engineering Test Reactor (ETR). His function typifies the whole L&N concept of reactor control — standardized components economically "packaged" by men experienced in both steam power and nuclear control.

Applied to the pressurized water-type ETR (built for the A.E.C. by Kaiser Engineers), this L&N control concept resulted in a skillfully integrated system — one that includes all of the reactor's operating and safety channels. A network of Speedomax® monitron recorders was also supplied, to guard constantly against radiation hazards.

In directing work on this system the project engineer drew on a 14-year personal working association with steam power instrumentation. He'd begun building his nuclear background long before his assignment as project engineer for the L&N control systems developed for the Penn State and University of Michigan Reactors.

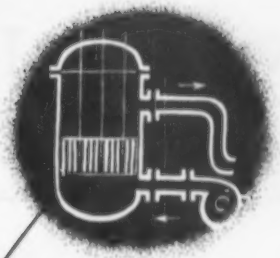
This project engineer, and others like him, serve as coordinators on every reactor control system produced by L&N. You can direct their experience to your own nuclear control problems merely by contacting us through your L&N office.

Write for our brochure "Control Systems for Nuclear Reactors." Leeds & Northrup Co., 4936 Stenton Ave., Phila. 44, Pa.

LEEDS & NORTHRUP
Instruments — Automatic Controls • Furnaces

Jrl Ad ND46-03(2)

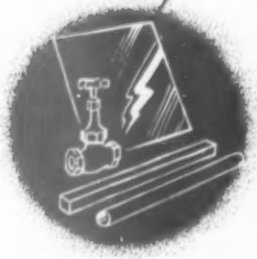
The metal of tomorrow... **TODAY**



REACTOR GRADE

Actual photograph of zirconium sponge prior to melting process.

...from the world's largest producer



COMMERCIAL GRADE

PROVEN METHODS—in production *now*. CARBORUNDUM METALS' hafnium separation, metal reduction and high temperature vacuum distillation processes assure zirconium sponge metal to meet the most exacting requirements. These methods are the result of many years of research and development.

PROVEN QUALITY—Soft, ductile, low-chloride zirconium sponge has already been delivered in quantity, meeting rigorous spectographic analysis requirements. Precise quality control is exercised over every pound of metal in every step of the process, from the zircon sand to the final product.

PROVEN PERFORMANCE—As the leading producer of reactor grade sponge for the A.E.C., CARBORUNDUM METALS has produced hundreds of thousands of pounds of on-specification sponge – not only meeting production schedules, but exceeding them. CARBORUNDUM METALS is now rapidly expanding its *proven* production facilities to provide *more* reactor and commercial grade metal for both existing and potential users.

For further information, contact

THE CARBORUNDUM METALS COMPANY
Akron, New York
Division of THE CARBORUNDUM COMPANY

Production Pioneer of ZIRCONIUM

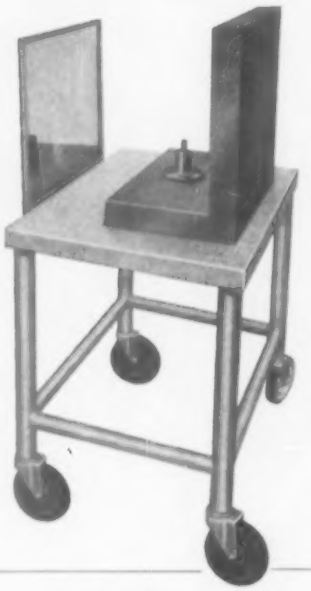
Ask to be placed on the mailing list of "More Zr Facts", the Zirconium Industry's first continuing source of technical information.

51-413

New Ray Stoppers

NATIONAL LEAD REPORTS RECENT DEVELOPMENTS IN LEAD SHIELDING

NEW ISOTOPE LOADING CART FOR HOSPITAL USE



This new Therapeutic Isotope and Radium Loading Cart is designed to provide maximum protection for hospital attendants who transport or load radioactive isotopes.

The cart comes equipped with an "L"-shaped shield, 16" x 16" x 10", that gives a solid 2 inches of lead protection.

Variations in side shielding are possible through solid wall shielding or through removable lead bricks. The unit can also be adapted for remote controlled finger rods.

The table has an 18" x 24" gauge stainless steel top standing 26" from the floor. It is furnished with 5" dia. x 1¼" tread conductive-type swivel casters complete with locking devices. A 15" x 16" framed plate glass viewing mirror mounted on one side completes the unit. Loading is performed manually while viewing into the mirror.

New Specially Designed Storage Vault combines portability with high shielding efficiency

A new portable Isotope Storage Vault has been developed that simplifies in-plant handling of radioactive materials. The unit features lead-in-stainless steel shielding and a stepped closure design that prevents beaming. Lead protection is 4" in all directions, around a hot cavity ⅜" x ¾". Handle studs, locking screws and side bars are all heavy steel. Heavy-duty, swivel-type casters make the vault easy to roll, easy to maneuver in tight areas. The vault is also easy to decontaminate.

NEW PORTABLE STORAGE CASK HAS NOVEL LID-LIFTING DEVICE

This small specially designed Isotope Storage Cask (about 500 lbs., 10¾" x 13½") provides all-around 3" lead protection, encased in stainless steel. Hot cavity is 4" dia. x 6" deep. Not only is this cask easy to move around the laboratory but raising and lowering the heavy cover is no problem at all. The rolling platform carries two uprights across which is a winch-like device. At the turn of the handle, steel cables attached to the cask lid raise or lower it. A ratchet arrangement holds the lid securely at any desired height.

PROTECTION AND PORTABILITY TEAM-UP IN THESE NEW LEAD-SHIELDING UNITS

More and more, hot labs and hospitals look to National Lead for shielding-with-extras. The units illustrated here are good examples of special jobs recently completed.

The lead shield itself provides the radiation absorption for which it was designed. The method of fabrication — casting, rolling or extrusion — insures maximum soundness and density. Stainless cladding is used according to customers' specifications. Where called for or indicated, the lead is bonded to the steel, using methods developed by National Lead in building lead-lined equipment for leading chemical processors.

The units shown here are, of course, custom made. We emphasize, however, our facilities for producing standard lead-shielded casks, vaults and shipping containers — and we invite your inquiries.

NATIONAL LEAD SHIELDING, NATIONAL LEAD COMPANY, *General offices: 111 Broadway, New York 6*

EBWR

"Today marks an event of historic significance in man's development of the atom for peaceful purposes. The reactor we are placing in operation today is the first of a generation of such reactors designed to provide electric power for our factories and our homes, power upon which the strength and future well being of this country vitally depends."

from Dedication address, Feb. 9, 1957, by Rep. Carl T. Durham, Chairman, Joint Congressional Committee on Atomic Energy.

EXPERIMENTAL BOILING WATER REACTOR PLANT
Argonne National Laboratory
Lemont, Illinois

TURBINE RATING
5000 kw — 600 psig — 488° F

ENGINEERING AUTHORIZED
August 25, 1954

FULL POWER GENERATION
December 29, 1956

FORMAL DEDICATION
February 9, 1957

SARGENT & LUNDY ENGINEERS
140 SOUTH DEARBORN STREET, CHICAGO 3, ILLINOIS

UCRL

. . . pioneers in nuclear energy since 1936

At the University of California Radiation Laboratory, Berkeley and Livermore, there is an unusual spirit among scientists and engineers — a spirit stimulated by association with pioneers in nuclear research who encourage development of new ideas, techniques, and individual initiative.

Since its founding in 1936, UCRL has contributed an impressive list of achievements to the world's knowledge of the atomic nucleus — from development of the cyclotron and Bevatron, to electromagnetic separation of uranium-235, to the discovery of the antiproton and antineutron.

These accomplishments have, of course, stemmed from an outstanding group of men working with unmatched laboratory facilities. But just as important — and the key, perhaps, to UCRL's successes — has been the spirit with which these men work.

For UCRL is managed and directed by scientists and engineers — men who are liberal with their own knowledge and enthusiastic in the encouragement of their teammates' new ideas and new techniques.

This is the constant and continuing spirit of UCRL. It is to be found in each new and expanded project — whether it involves pure or applied science. It keynotes work on nuclear weapon design, nuclear propulsion, controlled thermonuclear energy (Project Sherwood), and high current accelerators, as well as such problems as the application of radioactive substances to biology and medicine.

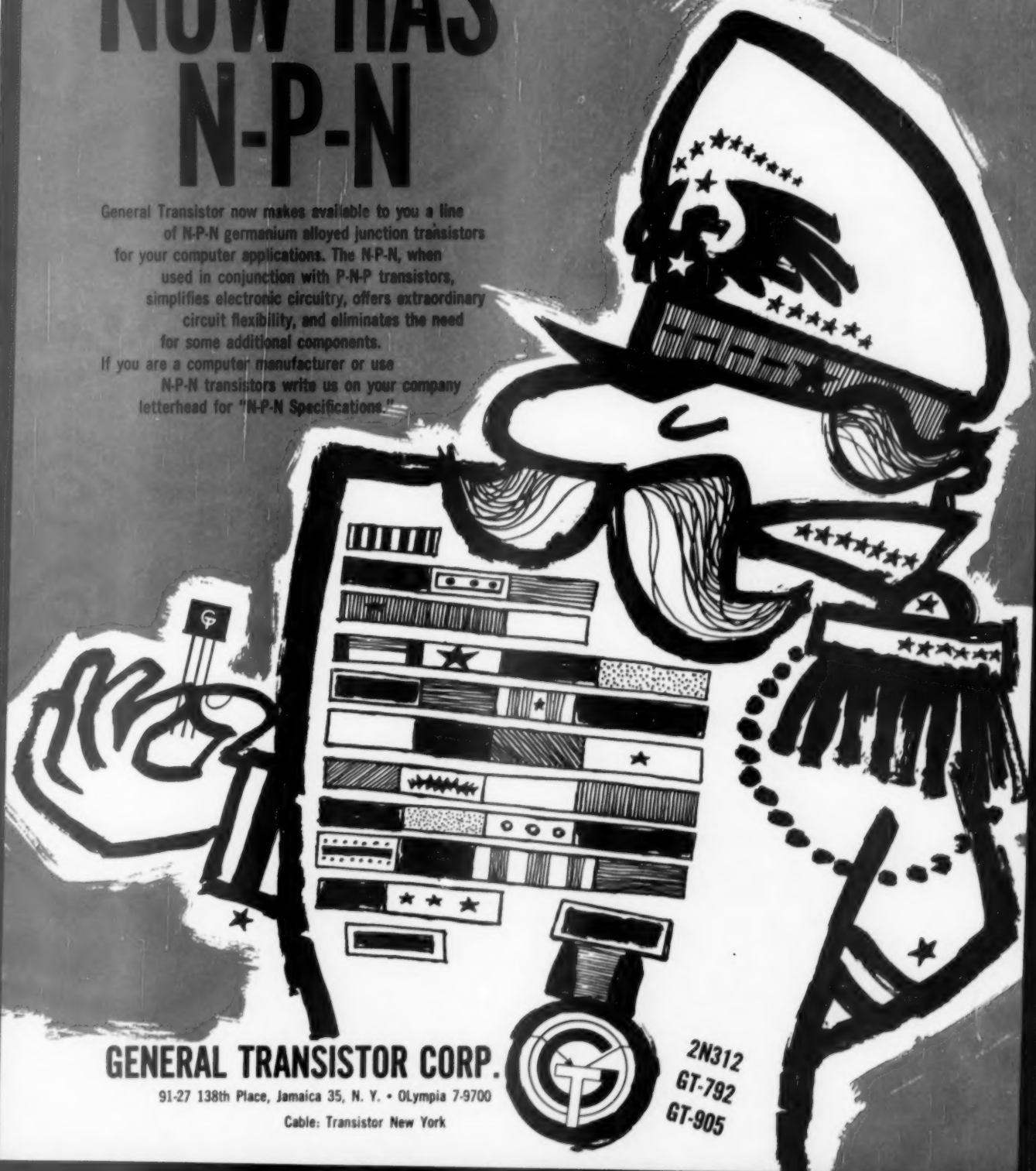
The UCRL "spirit" appeals to a particular kind of scientist and engineer — to men of ability and imagination, to men who wish to move forward and challenge the unknown. If you wish additional information, write to the Director of Professional Personnel, University of California Radiation Laboratory, Livermore, California.

UNIVERSITY OF CALIFORNIA RADIATION LABORATORY · BERKELEY · LIVERMORE

GENERAL NOW HAS N-P-N

General Transistor now makes available to you a line of N-P-N germanium alloyed junction transistors for your computer applications. The N-P-N, when used in conjunction with P-N-P transistors, simplifies electronic circuitry, offers extraordinary circuit flexibility, and eliminates the need for some additional components.

If you are a computer manufacturer or use N-P-N transistors write us on your company letterhead for "N-P-N Specifications."



GENERAL TRANSISTOR CORP.

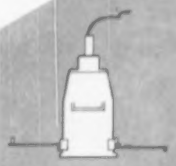
91-27 138th Place, Jamaica 35, N. Y. • OLympia 7-9700

Cable: Transistor New York

2N312
GT-792
GT-905

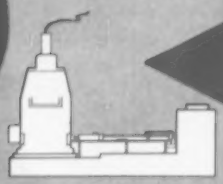
Tracerlab TGC-14 CARBON COUNTER

a better detector
for solid C-14
samples



1. Manual Sample Changer

2. Automatic Sample Changer



See it at
Booths 52-53
the Federation of
American Societies for
Experimental Biology.

3. Automatic
Chromatogram Scanner

FEATURES:

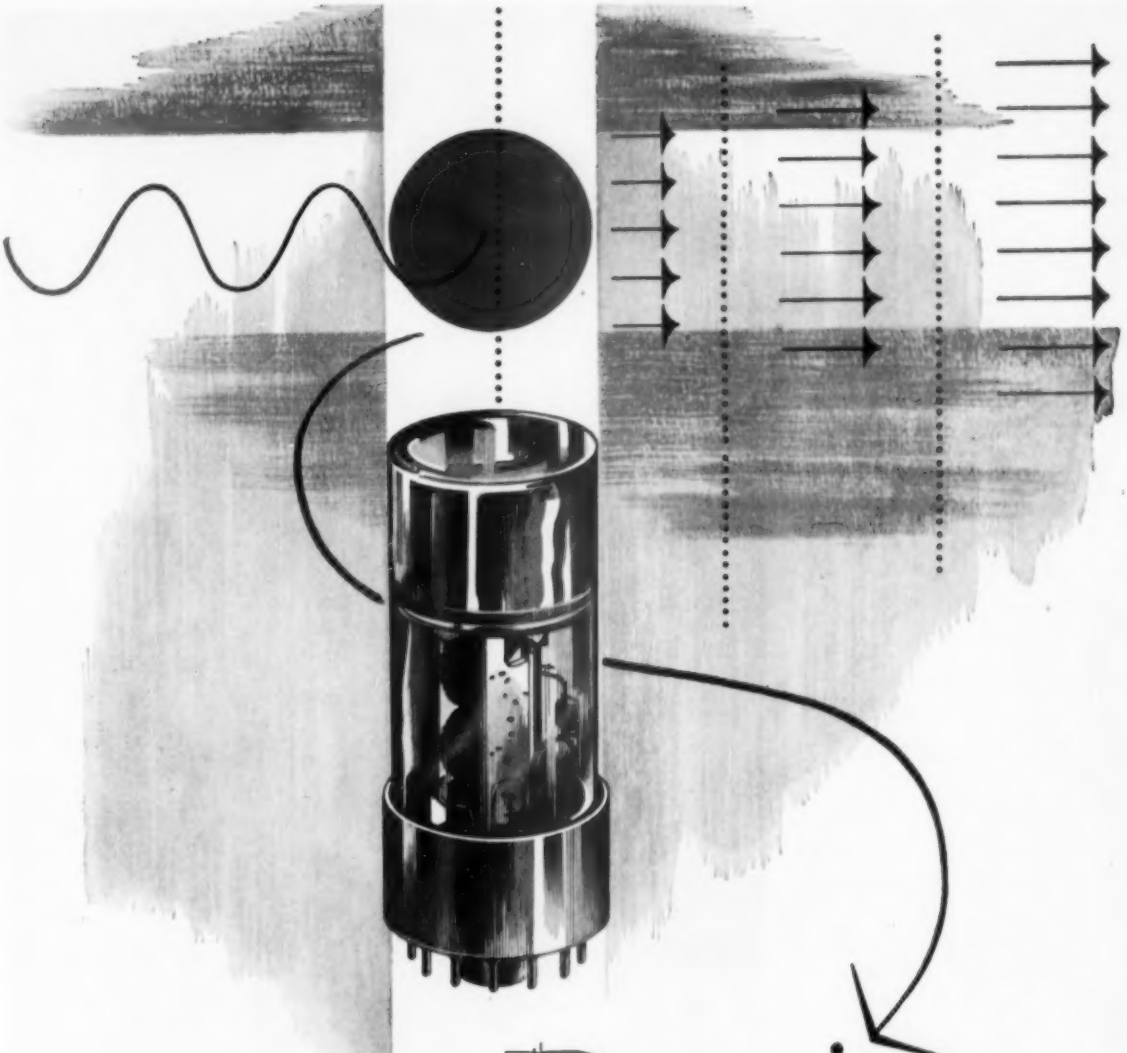
- **Low Background**
- **Rugged, Thin Window**
- **Manual, Automatic or Chromatographic Operation**
- **Excellent Reproducibility**
- **Simple, Trouble-Free Operation**

For full details on this outstanding new detector for counting solid samples of Carbon-14 and other low energy beta emitters, request Bulletin No. 84

Tracerlab

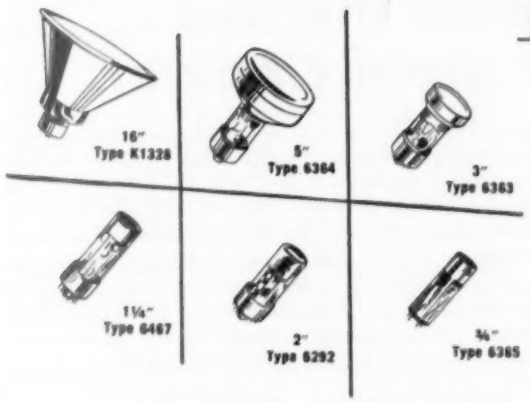
1601 Trapelo Road, Waltham 54, Mass.
2030 Wright Avenue, Richmond 3, California

Offices in principal cities throughout the world



Precise

PHOTOELECTRONICS*

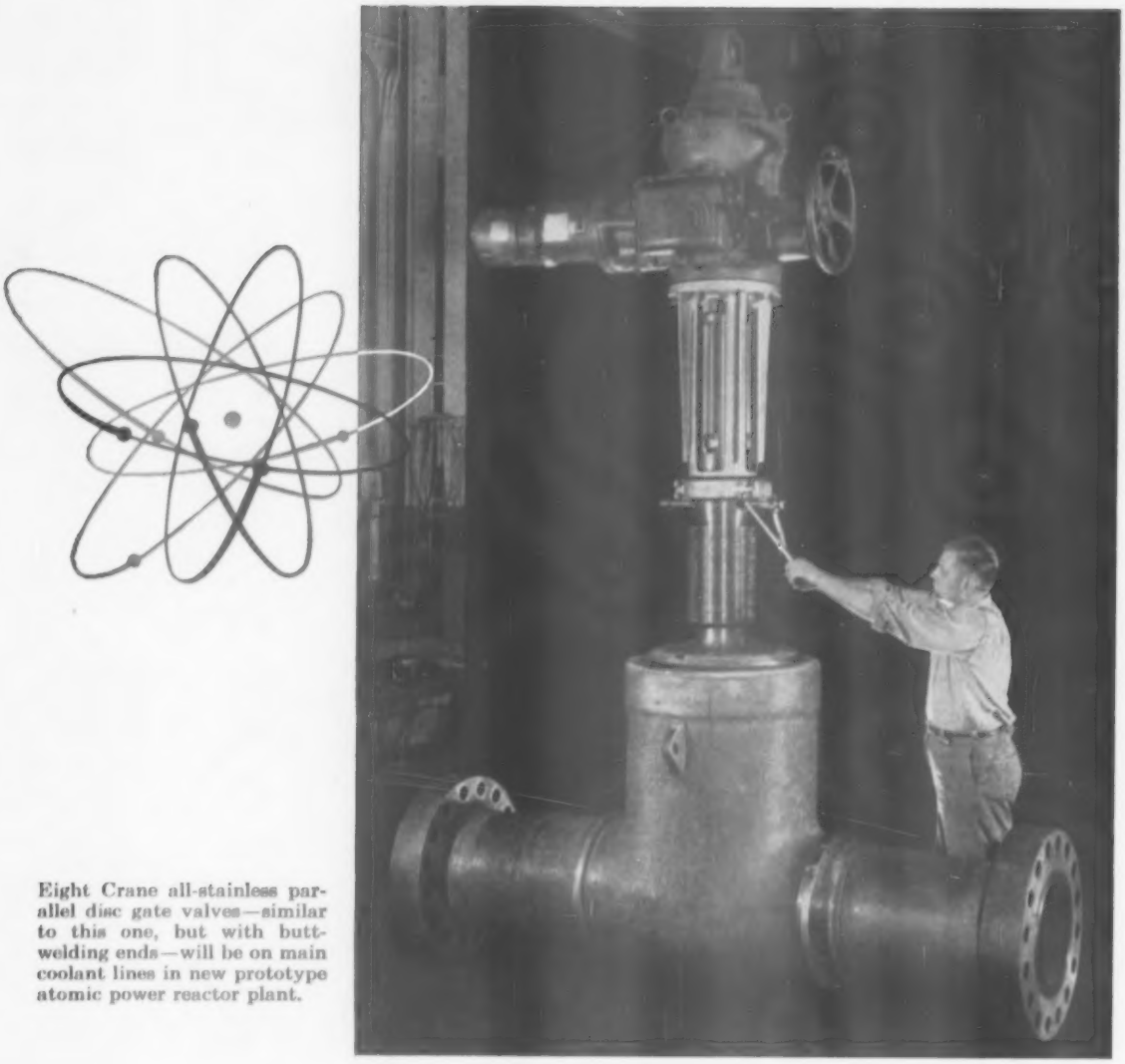


* The conversion of light input to highly magnified electrical output in a dependable, precise relationship.

Depend on Du Mont Multiplier Phototubes for precise quantitative and qualitative measurements. Available in a wide selection of sizes and electrical characteristics for every photoelectronic need.

DU MONT®

Industrial Tube Sales, **ALLEN B. DU MONT LABORATORIES, INC.** 2 Main Ave., Passaic, N. J.



Eight Crane all-stainless parallel disc gate valves—similar to this one, but with butt-welding ends—will be on main coolant lines in new prototype atomic power reactor plant.

AGAIN... Crane leads the way in flow control for atomic power

As the age of atomic power unfolds and expands, Crane continues to lead the way in flow control.

Crane equipment is already playing an important role in the mighty *Nautilus* and *Seawolf*—the Navy's celebrated atomic-powered submarines.

Now Crane valves are ready to make history again in the peaceful use of atomic energy—in the nation's first land-based atomic power plant.

Eight Crane stainless steel gate valves—similar to the one shown above—will be on the main coolant lines in the pressurized water reactor. Crane's broad experience in flow control for atomic power—dating from the beginning of this radically different field—assures low-cost, dependable service on this critical application.

Whether your future involves atomic energy for power or radioactive materials for processing—call on Crane for the right valves and fittings. You'll find Crane has the depth in research, engineering, and manufacturing abilities and facilities you're looking for.

CRANE VALVES & FITTINGS

PIPE • PLUMBING • KITCHENS • HEATING • AIR CONDITIONING

Since 1855—Crane Co., General Offices: Chicago 5, Ill. Branches and Wholesalers Serving All Areas

What does the stress-rupture test show about the usefulness of Inconel "X"?

The apparatus at right tells how long you can count on a metal under stress at high temperature.

At Inco, batteries of such machines test metals to destruction under all likely conditions of loading and high-temperature operation. These and other tests yield a wealth of valuable design information.

For example:

- They show that at 1350°F., few commercial wrought alloys meet specifications as high as Inconel "X"* age-hardenable nickel-chromium alloy.
- When Inconel "X" specimens are stressed as high as 25,000 psi. at 1450°F., they provide 1000-hour life.
- Up to 1500°F., the strength of Inconel "X" is outstanding under sustained or cycled stresses.
- The mean coefficient of expansion from 100 to 200°F. is 7.6; from 100 to 1500°F. it is 9.0 (units: 10^6 in./in./°F.)
- At elevated temperatures, red heat, Inconel "X" retains excellent hardness, resists abrasion, galling.

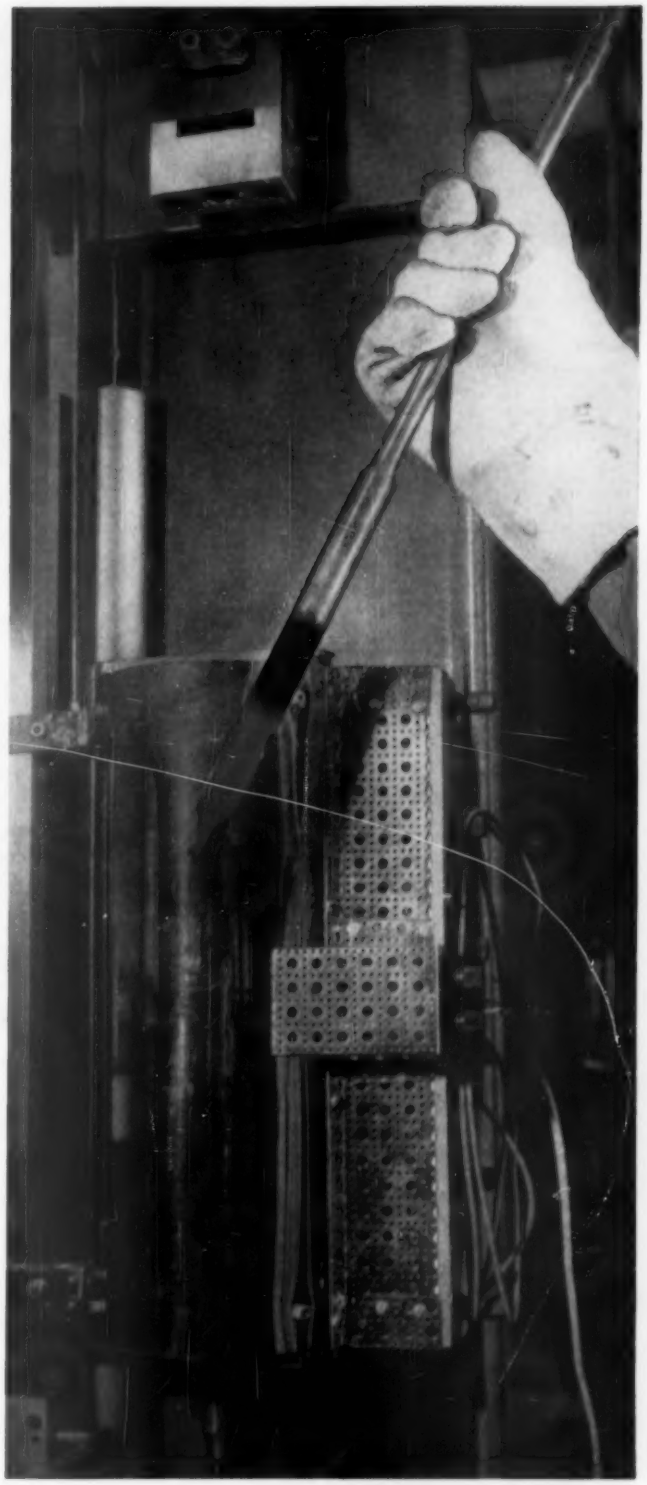
Add one more fact . . . very high resistance of Inconel "X" alloy to oxidation and corrosion at high temperatures.

You may find that Inconel "X" is exactly what you need for moving parts, springs, forgings, sheet metal parts operating at high temperatures. Or maybe one of Inco's other high-temperature alloys is indicated. Inco's Development and Research Division will be glad to make suggestions. Just write.

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.
*Registered trademark

INCONEL "X" Data Available

Inconel "X" is produced in most mill forms including pipe and extruded tubing. For complete data concerning forms available, properties, and fabrication write for the 79-page Inco booklet "Inconel 'X'."



INCO Nickel Alloys

Inconel "X" *for high strength at high temperatures.*

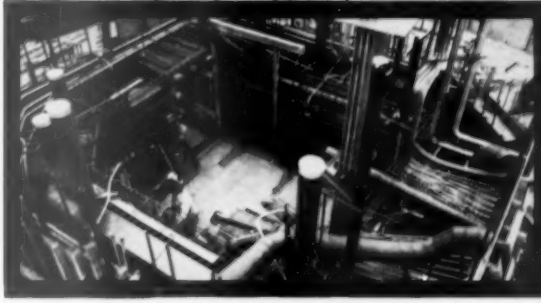
LIFELINE

••• — — — ••• These are the "call letters" of the U. S. Coast Guard. Watching over more than half a million square miles of our coastal waters, the rescue record of this famous organization is one of the great air-sea sagas of war and peacetime service. Helping to extend the Coast Guard's far-flung lifeline is the Martin P5M and the new P5M-2G, providing long-range sea reconnaissance for any emergency. Also, in active service with both the Atlantic and Pacific fleets of the U. S. Navy, ten squadrons of this famous seaplane—specially armored for anti-submarine warfare—are in operation today, from Norfolk to the Mediterranean and from Washington to the Orient.

MARTIN

BALTIMORE · DENVER · ORLANDO

M.I.T. reactor facility



Designed for advanced research in the biological as well as the physical sciences, this major reactor facility at M.I.T. is presently being engineered and constructed by ACF Industries, Incorporated. It will go critical late in 1957.

The M.I.T. installation is a heavy water reactor, using an enriched uranium core. Cooling of the D_2O will be provided by pure H_2O through a heat exchanger. The reactor is designed for initial operation at 1,000 kw; however, it is capable of being increased to 5,000 kw by the addition of extra heat exchanging equipment. A medical therapy facility for neutron treatment will be provided below the reactor.

The Nuclear Energy Products Division is staffed and equipped to design and build complete reactor facilities for power, research, materials testing, and other purposes. We cordially invite inquiries relating to design and manufacture of reactors, components and associated equipment.

ACF reactors currently under design and construction

- 1,000-5,000 kw heavy water research reactor for the Massachusetts Institute of Technology.
- 5,000 kw heavy water research reactor for the Italian National Committee on Nuclear Research.
- 20,000 kw light water materials testing and research reactor for Reactor Centrum Nederland.
- 30,000 kw light water materials testing and research reactor for Aktiebolaget Atomenergi of Sweden.
- 10,000 kw light water materials testing reactor for the Nuclear Engineering Test Facility, Wright-Patterson Air Force Base, Ohio.

Engineers and scientists interested in joining this large, well-staffed and well-backed group are invited to inquire into the many available opportunities.

nuclear energy products division 508 Kennedy Street, N.W., Washington, D. C.

ACF INDUSTRIES, INCORPORATED

METTLER BALANCES ARE TRULY MODERN

METTLER K-7T PRECISION BALANCE

Because...

Their design is based on sound principles . . .
They are very well constructed . . .
They are easy to operate. . . a pleasure to work with.

The METTLER precision balance, type K-7T, is an excellent example of such a truly modern balance. It is fast, sturdy, compact, easy to use, and above all, reliable. It has a taring device, which is fast and simple and lets you compensate for any container weighing up to 100 g. Capacity: 800 grams. Built-in mechanical weights: 700 grams. Range of optical scale: 100 grams, with scale divisions of 0.1 g. Precision: ± 0.03 grams.

HOW MODERN ARE YOUR WEIGHING METHODS?

Do you deprive yourself of the savings in time and money, which these balances can bring to you, and of the ease with which even untrained operators can work with them?

Let us show you what METTLER balances can do for you. Write to us today for our complete file on METTLER balances.

Mettler
INSTRUMENT CORPORATION
HIGHTSTOWN, N. J.

Announcing **THE DAYSTROM REACTOR TRAINING CENTER**

AND *Introducing* **D.A.R.T.**

A NEW PROGRAM FOR REACTOR CONSTRUCTION AND TRAINING

Designed to facilitate civilian research into the utilization of nuclear power, the D. A. R. T. (Daystrom Argonaut for Research and Training) Program has two significant phases:

COMPLETE D. A. R. T. REACTOR FACILITIES

At the Daystrom Reactor Training Center, West Caldwell, New Jersey — our nation's newest point of practical nuclear training — the company will manufacture, in quantity, low-cost D. A. R. T. Reactors capable of producing 10 kilowatts of power.

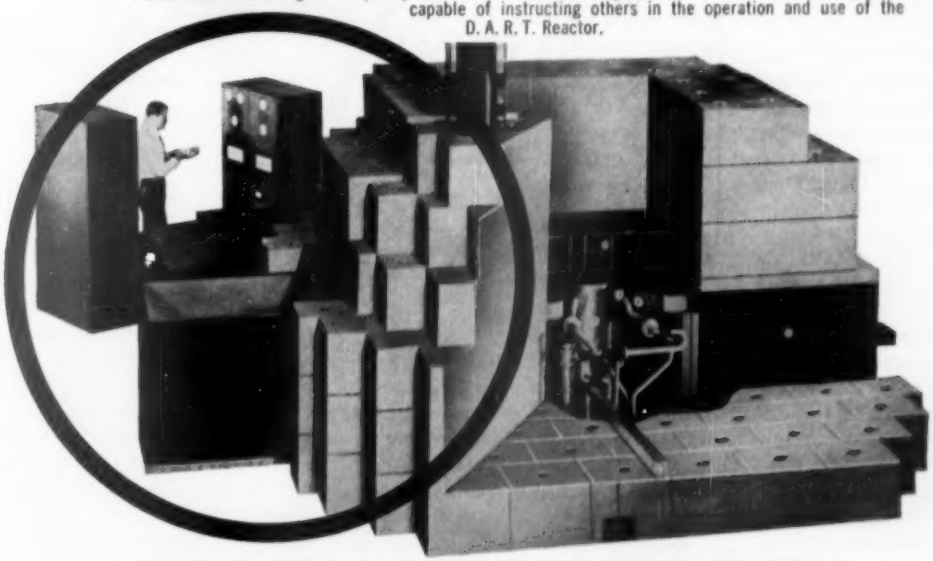
To implement the obtaining of these Reactors by colleges, universities, and industry, a comprehensive Daystrom D. A. R. T. Program will deal with **every** aspect of purchase, including:

(1) **TECHNICAL CONSULTATION** — to determine and design most suitable facilities.
(2) **SITE INVESTIGATIONS** — to evaluate and select best available location.
(3) **PREPARATION OF REPORTS** — to fulfill all existing A. E. C. permit requirements.
(4) **TRAINING** — of several months duration to prepare personnel for the A. E. C. license examinations.
(5) **MANUFACTURE AND INSTALLATION** — of the D. A. R. T. Reactor.
(6) **PREPARATION** — of normal and emergency operating procedures.
(7) **SUPERVISION** — of initial loading, start up and criticality.

D. A. R. T. REACTOR TRAINING

A specialized training course will be offered, at the Daystrom Reactor Training Center, to fully acquaint university faculty members and selected industrial personnel with the operation and application of research reactors. This course includes actual operation of the D. A. R. T. Reactor and lectures on basic reactor technology and theory.

Its curriculum is designed to qualify the individual for licensing by the A. E. C. as a reactor operator capable of instructing others in the operation and use of the D. A. R. T. Reactor.



CUTAWAY OF D. A. R. T. (DAYSTROM ARGONAUT FOR RESEARCH AND TRAINING) REACTOR

DAYSTROM NUCLEAR
Division of Daystrom, Inc.
WEST CALDWELL, N. J.

Additional information about all phases of Daystrom's new D. A. R. T. Program can be obtained by writing to Mr. A. Stanton, Director, Domestic Sales or Mr. K. Kirchhoites, Director, Foreign Sales.

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

OMR a promising approach to meet world's need for small to large power plants

An important goal of the Atomic Energy Commission's program to develop electric power from the atom is a low-cost reactor for plants with gross outputs of 10 megawatts or more. Such plants are particularly suited to areas that need relatively small increments of additional power, and to those parts of the world where coal, oil, and water-power are scarce or costly.

The OMRE (Organic Moderated Reactor Experiment), which ATOMICS INTERNATIONAL is now building at the National Reactor Testing Station in Idaho, is one of the more promising types for this purpose. The new experimental reactor was pioneered by ATOMICS INTERNATIONAL – from preliminary design to prototype.

It will be used to investigate the rate of degradation of organic fluids, the properties and compositions of the equilibrium mixture in the reactor, and the effect of organic fluids on heat-transfer surfaces. Results of these experiments will be incorporated into the nuclear power plants ATOMICS INTERNATIONAL is planning for Piqua, Ohio and a Latin American country.

Basic advantages of the OMR are small size, compact core with good neutron economy, and elimination of problems with high-pressure primary coolant circuits and uranium-coolant reaction hazards. Its safety features are outstanding. The high boiling point of the organic moderator-coolant fluid permits a low-pressure system. There are no chemical incompatibilities between coolant and uranium or coolant and water, and no unusual corrosion problems. Because of its fluid moderator—an isomeric terphenyl—the OMR has a negative temperature coefficient of reactivity, which acts as a governor in case of power surges or excess power levels. The organic fluid becomes only slightly radioactive, which makes the entire heat-transfer system relatively accessible.

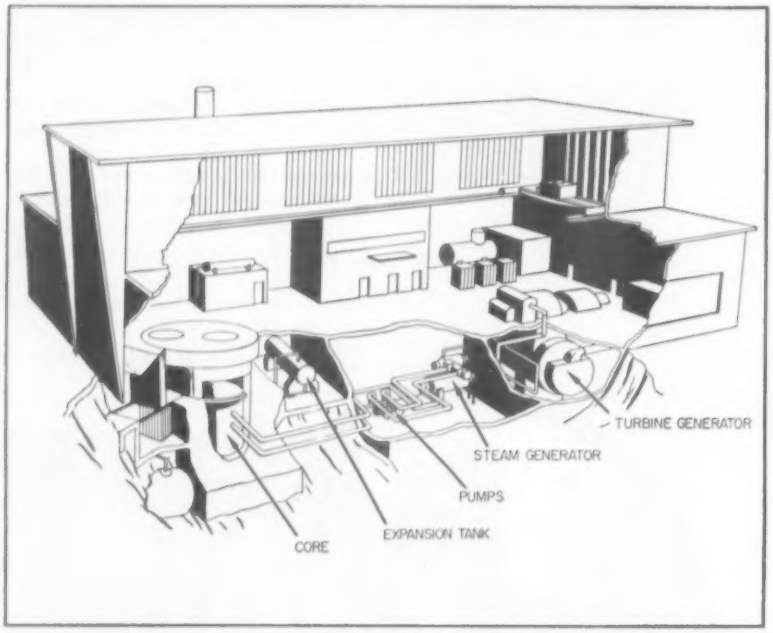
A typical power plant, such as the one proposed for Piqua, Ohio, has a gross electric output of 12,500 kilowatts and a heat output of 45,500 thermal kilowatts. It produces steam at a pressure of 415 psig (29 kg/cm^2) and a temperature of 550°F (288°C).

The reactor core is heterogeneous, with fuel elements and control rods immersed in the moderator-coolant fluid and contained in a thin-walled core tank. The fuel is uranium slightly enriched in U^{235}.

Power costs for this reactor, including both capital and operating charges, are estimated at 18 mills per kilowatt-hour. Power costs will be significantly lower in larger OMR plants. Lower power costs are also expected to result from advances in OMR technology.

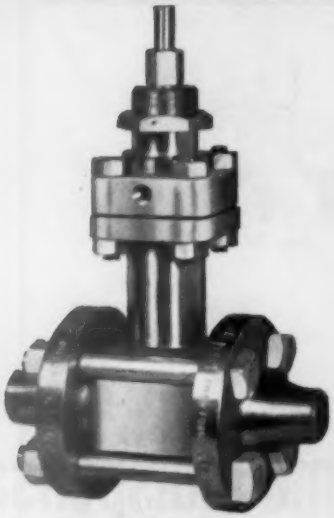
Atomic power for supertankers. The AEC has assigned ATOMICS INTERNATIONAL the challenging design study to adapt the OMR for maritime use. The OMR, considered a promising possibility for ship propulsion, is expected to be particularly suitable for supertankers. The OMR offers the safety of a low-pressure system, low construction costs (because it can be built of aluminum and mild steel instead of more expensive zirconium and stainless steel), and low maintenance costs.

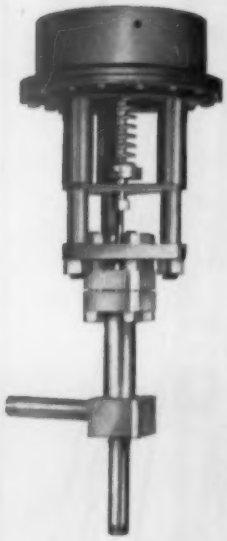
ATOMICS INTERNATIONAL is staffed and equipped to help you with any phase of reactor development. Please write: Director of Technical Sales, Dept. C-4, ATOMICS INTERNATIONAL, P. O. Box 309, Canoga Park, Calif. Cable address: ATOMICS.

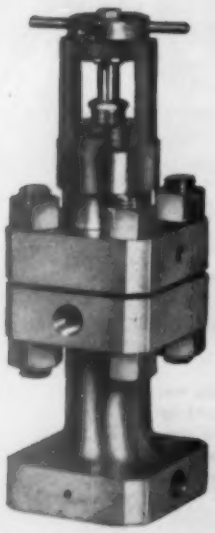


Typical OMR Central Station Nuclear Power Plant

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
PIONEERS IN THE CREATIVE USE OF THE ATOM







ANOTHER NEW IDEA FROM

FULTON SYLPHON

PACKLESS VALVES

YOU CONNECT AND FORGET

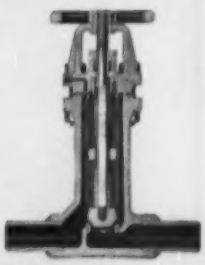
Some valves are good for severe corrosives, others for high pressures and temperatures, but these Fulton Sylphon Packless Valves are *complete* valves capable of mastering the toughest possible combination of conditions in atomic energy plants and grueling chemical processes. They assure utmost safety in handling hazardous materials, require no periodic maintenance, and practically eliminate down-time.

Typical of how Fulton Sylphon matches valve to process, these valves are made of stainless steel throughout, with the valve body machined as one unit from solid bar stock. And to prevent leakage or contamination, a SPECIAL SYLPHON® BELLOWS in multi-ply stainless steel forms a permanent, leak-proof seal for the stem. That is why they tame the severest corrosives inside and out. This is the reason, too, why these valves provide a high safety factor in high temperature-high pressure service.

These and other Fulton Sylphon Valves are available in many types, sizes, and metals—all with packless construction for greater safety, less maintenance and longer runs "on stream."

SEND TODAY FOR BULLETIN GV-813

A SPECIAL SYLPHON BELLOWS which forms the permanent, leak-proof stem seal on all Fulton Sylphon Packless Valves offers four outstanding features. It is (1) cold-worked for greater resiliency and longer life, (2) seamless, without welded seams to break and leak, (3) formed in multi-plies for greater strength, and (4) made in the right metal for service requirements.



Mr. Controls

Robertshaw-Fulton

CONTROLS COMPANY

FULTON SYLPHON DIVISION · Knoxville 1, Tennessee

How NUCLEONICS became indispensable ..

* *As you know, our (CROSSROADS) business is the disposal of radioactive waste materials, explosives, poisonous gases, etc. While we do confine our personal pick-up service to a 500-mile radius from Boston, still we were able to take advantage of your inquiries from all over the country. That's because we also provide shipping facilities (proper containers and instructions) to meet the laws for inter-state transportation.*

McGRAW-HILL PUBLICATION . . . 330

Crossroads

MARINE DISPOSAL CORPORATION
26 T WHARF BOSTON, MASS.
LA 3-4908

JOHN C. SANTANGELO
55 UNDERWOOD STREET
BELMONT, MASS.
HE. 5-5619

GEORGE C. PERRY
901 BOYLSTON STREET
CHESTNUT HILL, MASS.
AS. 7-7805

Mr. Phillip H. Hubbard, Jr.
District Manager
NUCLEONICS
330 West 42 Street
New York 36, New York

Dear Phil:

This is written on impulse--to tell you how small-space advertising in NUCLEONICS has tripled our business since July, 1956!

That first one-sixth of a page ad in July brought us inquiries that resulted in sales and new customers at the rate of one-a-day for the first twenty days. On the twenty-second day, it brought us two new customers (quite a return on an investment of $69.17!)

Since that time, we have placed another sixth-page and two-third page advertisement in NUCLEONICS; and the inquiries are still coming in.

Due to the nature of our business, an inquiry to us invariably means a sale. And this sale soon becomes a customer. Thus, we consider the leads which we receive from NUCLEONICS not inquiries but customers.

We started our business in 1946. But in the past five months we have tripled the volume--and it's all due to this modest NUCLEONICS advertising program.

*

To sum this up, let me quote my partner, who said: "We now consider our NUCLEONICS advertising as important as our rent."

Sincerely,

George C Perry

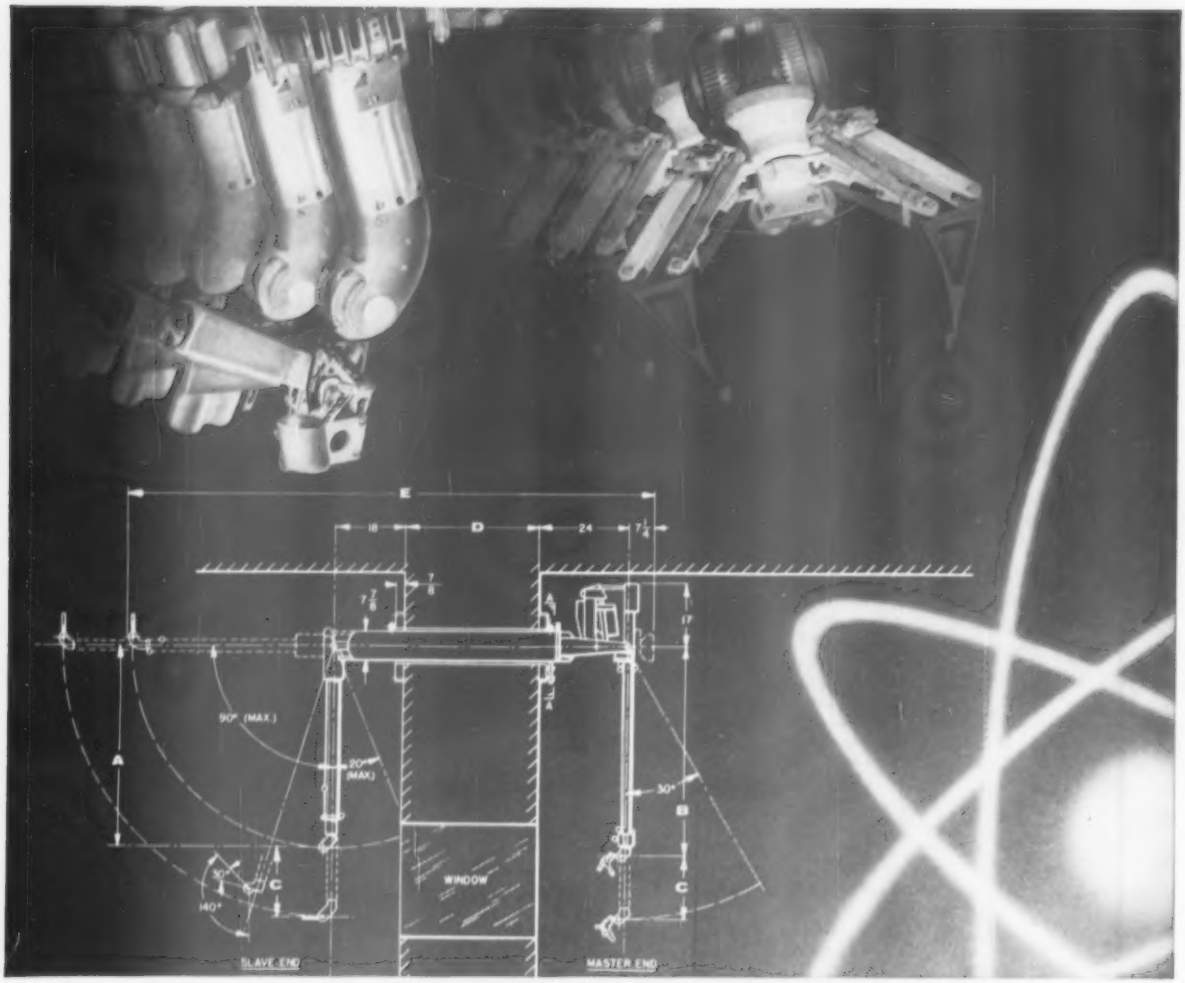
George C. Perry
President

DISPOSERS OF

- RADIOACTIVE WASTE
- EXPLOSIVES
- PYROFORIC MATERIALS
- POISONOUS GASES
- FLAMMABLE MATERIALS
- CONTAMINATED EQUIPMENT
- TOXIC MATERIALS
- ACIDS AND CAUSTICS

SALVAGE TUG
IRENE MAY
MARINE PHONE

WEST 42ND STREET . . . NEW YORK 36, N. Y.



AMF MANIPULATORS

for durability and uniformly sensitive touch

AMF ATOMICS—the nation's leading designer and producer of radio-active materials handling equipment—produces a complete line of Model 8 Master-Slave Manipulators, uniformly fashioned to the highest possible precision standards.

Quantity production, made possible by the large demand for AMF Manipulators, assures not only uniform ruggedness for durability under field conditions, but complete parts interchangeability as well. It means immediate delivery from inventory for most models.

And because AMF units are produced in quantity, you can be assured that each unit has the same sensitive, "glove-like" feel as every other. Such uniform performance eliminates delays in operator adjustment to variations in touch of other manipulators.

Unexcelled for dexterity and all-around reliability, the AMF Manipulator Argonne Model 8 can be equipped with a variety of special-purpose slave ends to perform the most specialized of hot cell operations. Though highly sensitive, it can handle weights up to 30 lbs. and more. And it can easily be transferred from one through-wall position to another to provide maximum usefulness.

For manipulators, or radio-active materials handling equipment of any kind, get in touch with AMF ATOMICS today.

All Models Available With Right or Left Hand Grip

Model Number	A	B	C	D	E
3666	52¾	55¾	36	24	127¼
3672	52¾	55¾	36	30	133¼
3678	52¾	55¾	36	36	139¼
3684	52¾	55¾	36	42	145¼
3685	52¾	55¾	36	46	149¼
3690	52¾	55¾	36	48	151¼
3966	55¾	58¾	39	24	130¼
3972	55¾	58¾	39	30	136¼
3978	55¾	58¾	39	36	142¼
3984	55¾	58¾	39	42	148¼
3988	55¾	58¾	39	46	152¼
3990	55¾	58¾	39	48	154¼

AMF ATOMICS

AMF ATOMICS Inc.
AMF Building • 261 Madison Ave. • New York 16, N. Y.
Subsidiary of AMERICAN MACHINE & FOUNDRY COMPANY

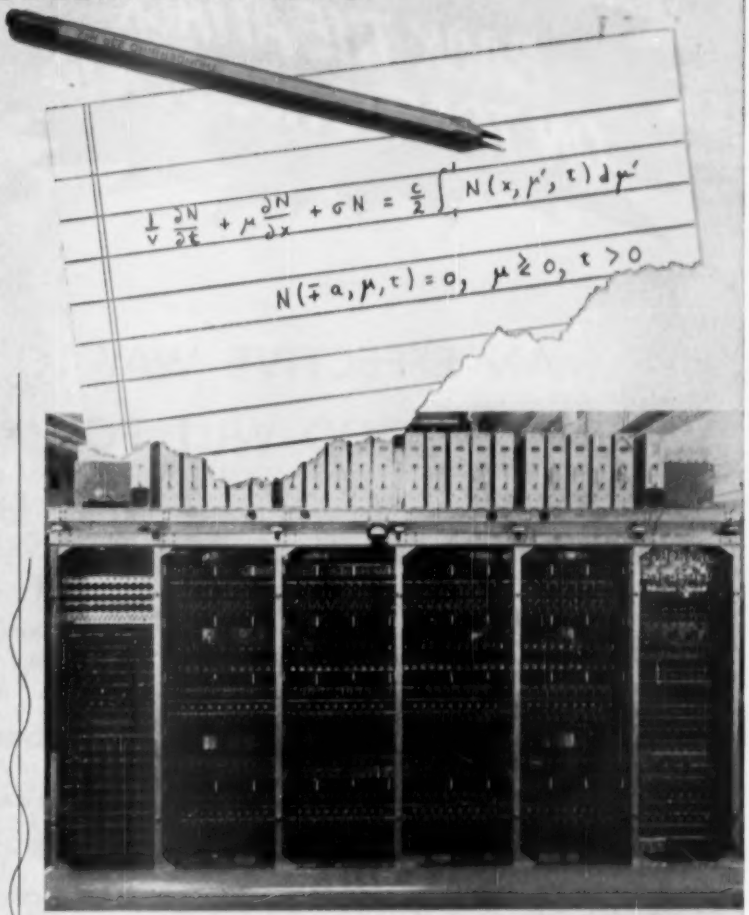
● Radiation Process Equipment ● Power and Research Reactors ● Reactor Control Systems ● Radio-active Materials Handling Equipment

another example of exciting work at los alamos...

BREAKING PROBLEM BARRIERS

The linearized Boltzmann equation shown at the right describes the transport of neutrons in a slab. Its mathematical structure was first completely worked out at Los Alamos. This is only one of the many fundamental problems in disciplines ranging from pure mathematics through biology that are yielding to newly developed methods of experimental and theoretical analysis.

The Laboratory has entered a new phase of scientific endeavor. Pioneering activities in the unexplored realms of nuclear power, nuclear rocket engines, and controlled thermonuclear power have been added to its weapons program; experiments are being planned and carried out at pressures and temperatures far beyond any previously created by man. These activities exemplify the imaginative approach by which the Laboratory maintains its preeminence in scientific achievement.


$\frac{1}{v}\frac{\partial N}{\partial t} + \mu\frac{\partial N}{\partial x} + \sigma N = \frac{c}{2}\int_{-1}^{1} N(x,\mu',t)\,d\mu'$
$N(\mp a, \mu, t) = 0, \quad \mu \gtrless 0, \quad t > 0$

Mathematical support for many of the Laboratory's programs is given by the Theoretical Division, which also pursues its own investigations in hydrodynamics, magnetohydrodynamics, computer theory and design, and other fields. The vast amount of computation involved has brought about the creation at Los Alamos of the largest known computing center devoted exclusively to scientific work.

The "Maniac" (above) is one of the many advanced computers in use at the Laboratory.

Los Alamos Scientific Laboratory is a non-civil service operation of the University of California for the U. S. Atomic Energy Commission.

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

AN EFFECTIVE WAY TO DEVELOP VALUABLE GOOD WILL FOR YOUR COMPANY

. . . and help to do a life-saving job at the same time

You can achieve lasting good will for your company—the kind of good will that results in friendly relations with every group in your community. And you can help to save precious lives at the same time, by putting your company's efforts behind the nation-wide campaign against traffic deaths.

During 1956, the national total of highway deaths was over 40,000—the highest figure in our history. The cost to the country of these wasted lives is incalculable.

But the picture wasn't entirely black. In many areas—in small towns and big cities—the terrible upward trend was reversed.

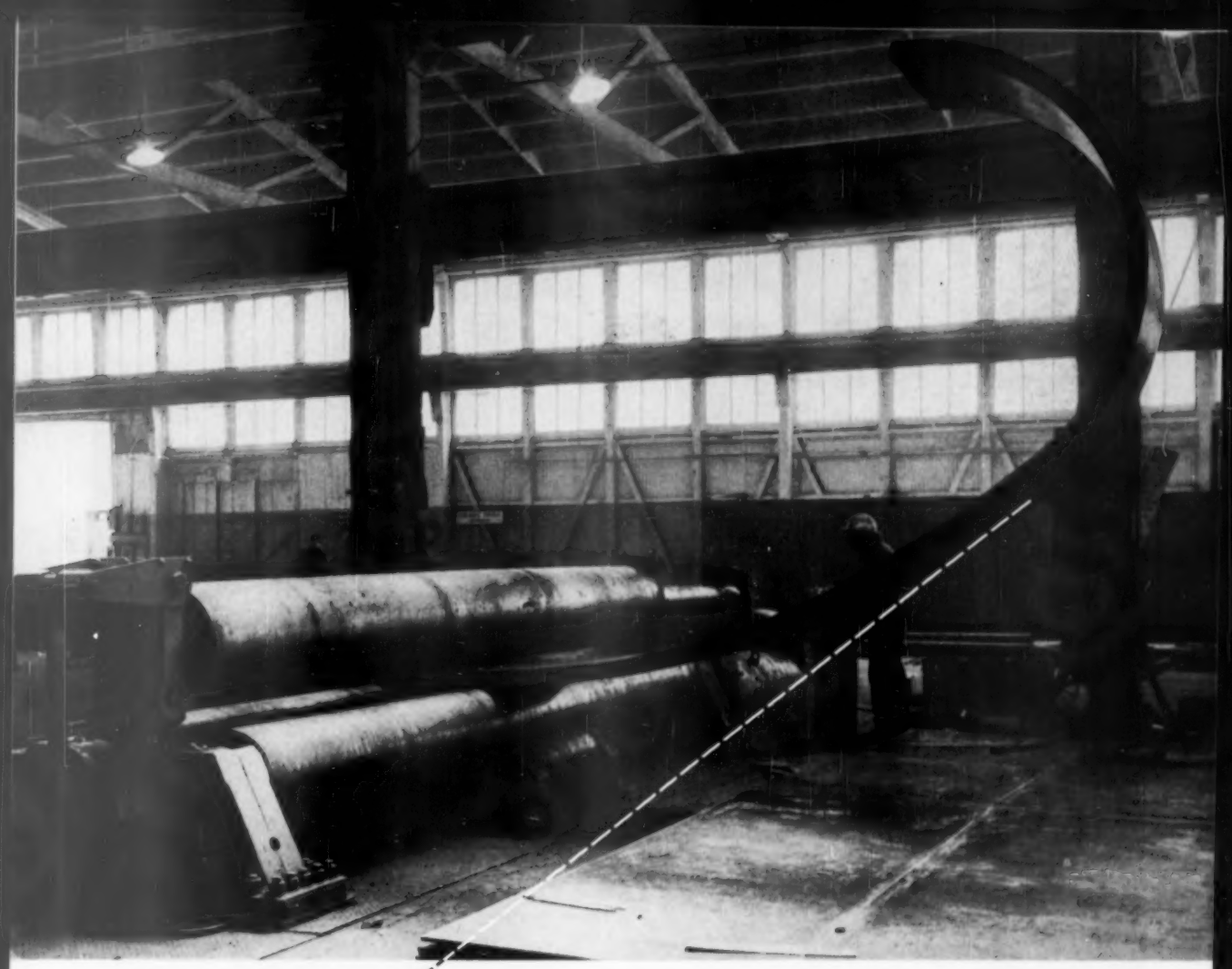
This was accomplished by community action—by business leaders, civic organizations, church, fraternal and PTA groups joining together with law enforcement agencies in an all-out attack on traffic deaths.

The figures prove it. Wherever people get together to do something about traffic safety, *deaths go down.*

BACK THE ATTACK ON TRAFFIC ACCIDENTS!

Your company can perform an invaluable service for your community, and for the country as a whole, by pitching in and helping in this life-saving crusade. For full information on what you can do — and how you can do it—write The National Safety Council, Chicago 11, Illinois.

Published in cooperation with
The National Safety Council
The Advertising Council



GIRDLE IN THE MAKING

PACECO

NUCLEAR
"TAILORS OF STEEL" ®

This is one plate being rolled to shape for the Boiling Water Reactor now under construction by Paceco for General Electric Co.

To safely withstand the design pressure of 1215 p.s.i.g. at 578° F, shell is fabricated from 3⅜" clad steel with ¼" 304L stainless steel cladding and A212 Grade B mild steel backing.

Basic size of 60 ton reactor vessel was determined by General Electric. Entire design and engineering was supplied by Paceco.

Here are 4 Paceco gained-through-experience skills you may be seeking for design and fabrication of your nuclear equipment:

1. Skill in welding and heat treating of steel and alloys, both light and heavy gauge.
2. Skill in fabricating of corrosion-resistant metals and alloys.
3. Skill in producing heavy equipment to extremely precise mechanical tolerances.
4. Skill in designing and building equipment to resist extreme pressures and intense temperatures.

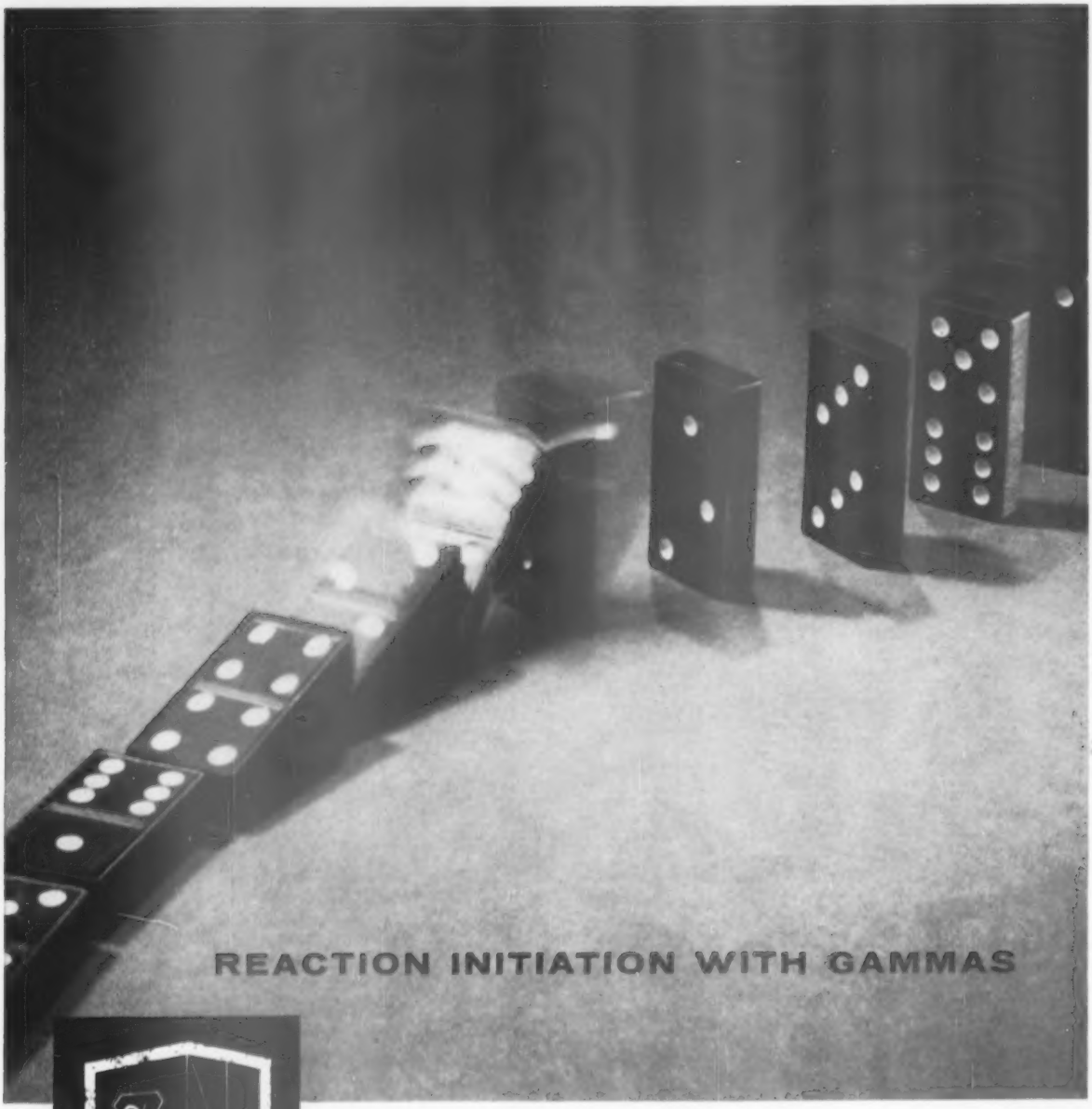
Some units we have built direct from buyer's plans. In other instances, however, Paceco engineers work with the buyer *at the designing stage*. Experience has proved this consultation may sharply lower initial cost, improve operational efficiency and reduce maintenance. We invite consultation on your requirements.

PACIFIC COAST ENGINEERING COMPANY

ENGINEERS • MACHINISTS • FABRICATORS
Alameda, California, LAkehurst 2-6100

PACIFIC COAST ENGINEERING CO., INC.
New York 17, 51 East 42nd Street, OXford 7-1475

REPRESENTATIVES
Pasadena 8, Calif., 3018 E. Foothill Blvd., RYan 1-9373
Kansas City 12, Mo., 4706 Holly Street, PLaza 3-3737
Houston 2, Texas, 3619 Robinhood, MOhawk 3504



Gamma radiation to initiate chemical chain reactions is available with sources of Cobalt 60 in strengths up to 50,000 curies for applications as diverse as the vulcanization of rubber, polymerization of synthetic resins and the synthesis of chemicals.

Nuclear Systems can provide a complete radiation package —sources, equipment, instrumentation, training and facility design.

NUCLEAR SYSTEMS

A DIVISION OF THE BUDD COMPANY

Philadelphia 32

Fast Breeders Are Essential to Future Atomic Power

A statement by HANS A. BETHE*

One of the most compelling reasons for developing atomic power is to extend our fuel reserves. We hear that our natural oil supply will become insufficient in two or three decades, and that coal reserves, although much larger, are also limited. It is likely that in 30 to 50 years a large fraction of our power will be derived from atomic energy. However, power demands are increasing at such a rapid rate that even the energy available from atomic resources could soon be used up unless these resources are fully employed.

It is clear that a breeder will be of the utmost importance for a large-scale atomic-power economy. If we use only the isotope U^{235}, which is directly fissionable, then all the uranium reserves now known to exist in the world will give *less* energy than the known reserves of coal. This is because U^{235} is only 0.7% of the uranium we find in nature. If we learn to use breeders we can use *all* the uranium instead of just the U^{235}, because a breeder will convert the nonfissionable material U^{238}, which constitutes 99.3% of natural uranium, into fissionable plutonium. This will extend the supply of atomic fuel more than a hundred fold. Only if we can do this will atomic energy give us a real improvement in our fuel reserve. If we succeed the uranium reserves will outlast the reserves of our fossil fuels more than 50 times.

Fast breeders seem to me indispensable for this purpose. In uranium-fueled thermal and intermediate reactors less plutonium is produced than U^{235} is consumed. But in a fast reactor the production of plutonium will be greater than the consumption of U^{235}. Ultimately when plutonium can be used as a fuel for a fast reactor, one hopes to produce in a breeder at least 1.5 plutonium atoms for each plutonium atom used up as fuel. Such a breeder would then be like a coal furnace which makes more coal than it uses up. The development of breeders of this kind is a most important measure of the conservation of our precious atomic fuel.

---

* Dr. Bethe is Professor of Physics at Cornell University. Although he is most famous for his contributions to the basic theory of the nucleus, he has always been interested in atomic-power matters. During World War II he was Chief of the Theoretical Division of the Los Alamos Scientific Laboratory. At the present time he is a consultant for Atomic Power Development Associates, Inc.

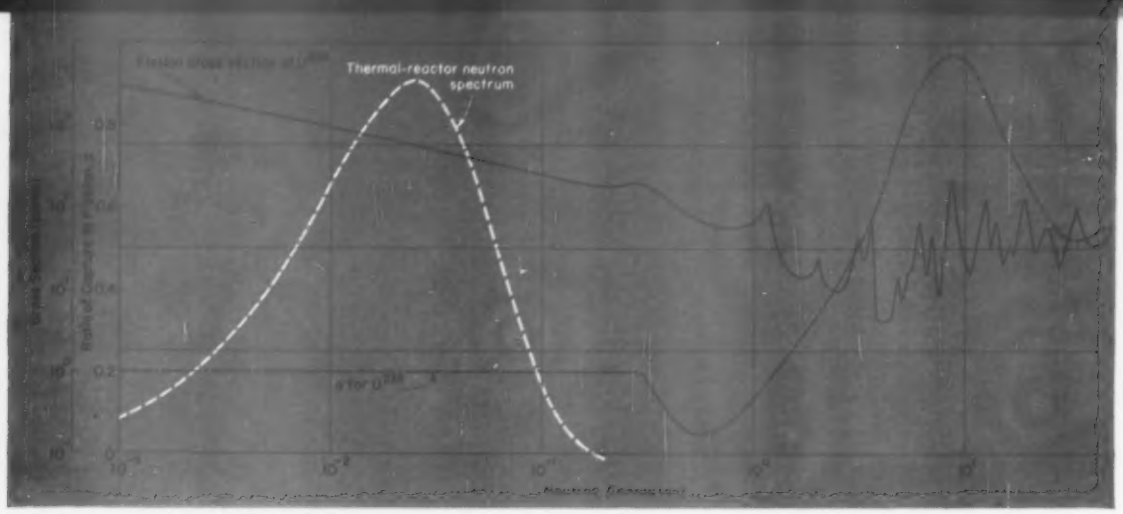
The statement published here is a portion of the testimony presented by Prof. Bethe at the AEC hearing on January 8 concerning the Enrico Fermi Fast Breeder Reactor.

NUCLEONICS Reports on:

Problems and Prospects 62

AEC's Fast-Reactor Program 67

The Enrico Fermi Reactor 68



AT THERMAL ENERGIES α is moderate, fission cross section high. Thus breeding ratio is not quite 1.0 but critical mass is low .

Fast Breeder Power Reactors—

Aside from their long-term role as plutonium breeders fast reactors could become competitive as power producers. At the moment four major difficulties stand in the way

BECAUSE the fast-breeder power reactor is the only reactor type that can breed Pu from U^{238} it will certainly find a place in any future large-scale atomic energy economy. How large this role will be, however, will depend not so much on the ability of the fast reactor as a breeder but more on its ability to compete successfully with other reactor concepts as a producer of commercial power. At present four basic difficulties tend to make the fast-reactor concept less attractive for large-scale power plants:

1. Need for operation at a high core-power density.
2. Problems of sodium technology.
3. High fuel costs because of large inventory and frequent reprocessing.
4. Criticisms have been made concerning fast-reactor safety.

High Power Density

High power density is an intrinsic feature of the fast power reactor and calls for heat-transfer performance not usually encountered in industry. Because the active core of a fast reactor is inherently smaller than the core of a thermal reactor for the same total power, the power density in the fast-reactor core must be an order of magnitude greater than the power density in a typical thermal reactor. To accommodate this high power density, high heat-transfer rates must be provided for in the core design.

In addition to using liquid metal as a coolant, the designer must use finely divided fuel to provide enough surface area for heat transfer. Thus, fuel-element thicknesses and coolant-channel widths are small in a fast power reactor. In the Enrico Fermi Fast Breeder Reactor, for instance, a fuel-element assembly consists of 144 fuel pins, 0.158 in. in diameter, 30 in. long, spaced 0.021 in. apart.

In addition to being thin the fuel pins must be made and assembled accurately.

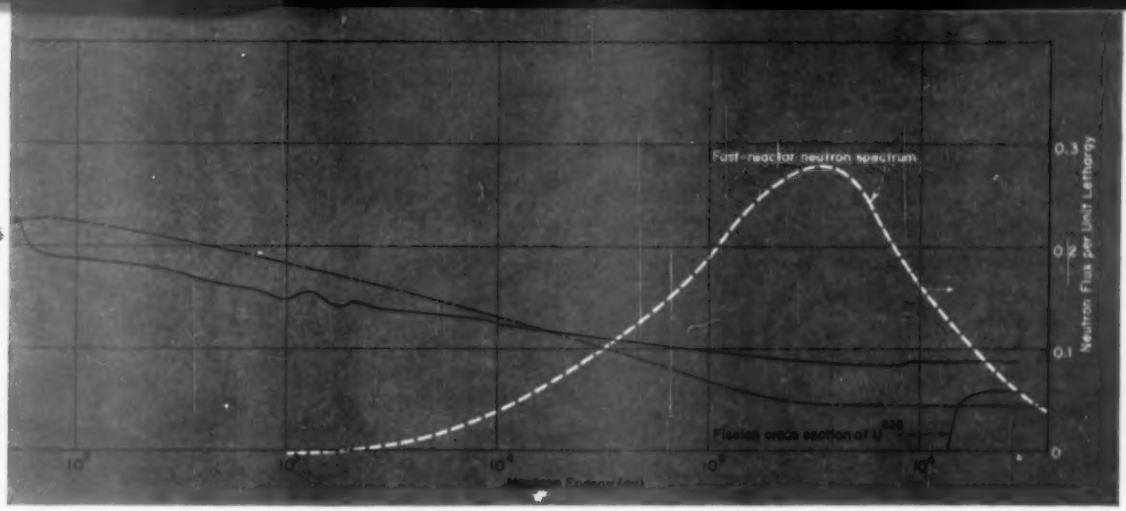
Since the power density is never uniform over the core and since dimensions and physical properties of individual elements will vary to some extent from the precise design values, the operating temperatures of some elements in the core will always be significantly above the average value. The average fuel operating temperature (and thereby the thermal efficiency) is then limited by the temperatures of these "hot elements."

Thermal efficiency can be improved by making the fuel-element temperature distribution as uniform as possible. Fast-reactor designers minimize the effect of spatial power variation by rearranging core materials and differentially orificing coolant flow channels.

The effect of variations in the properties and dimensions of individual fuel elements can be offset only by specifying strict design tolerances for the fuel-element components. Thus the basic parts of a fast-reactor core are not only smaller but must be fabricated and positioned with greater precision than would be required in thermal reactors having the same thermal efficiency. The additional expenses for constructing and maintaining the more finely divided core represent an economic penalty for the fast-reactor concept.

Sodium Technology

Liquid-metal cooling is another necessary feature of fast-power-reactor designs. A fast reactor needs a coolant that does not moderate neutrons and has good heat-transfer properties. Liquid metals in general fulfill both these requirements. Sodium in particular has outstanding heat-transfer properties and does not attack containers made of widely used structural materials like low-carbon iron, stainless steel and Inconel. In addition the melting point of sodium is low enough to be used with ordinary structural materials, and its boiling point is high enough to allow a high thermal efficiency. For these reasons all fast power reactor designs use sodium (or



. . . AT HIGH ENERGIES α is small, fission cross section low. Thus breeding ratio is greater than 1.0 but critical mass is high

Their Problems and Prospects

sodium-potassium as the coolant.

Although enough information exists today to indicate that a full-scale sodium-cooled reactor could be constructed and made to work, no one has yet demonstrated that the operation of such a system would be feasible in a commercial power plant. Systems having primary sodium and secondary water cooling, compared with systems with only water circuits, require heat exchanger and piping welds of much greater reliability. Liquid-metal system components, pumps, valves, and instruments are beginning to appear on the commercial market, but they need considerably more engineering development before they can be used with as much confidence as the more familiar components used in water systems.

To prevent plugging and corrosion in the coolant channels and piping, the amount of sodium oxide present in the system must be kept small. The control of this contaminant over a long period of time may prove to be a major problem for large sodium systems.

The scarcity of experience with sodium systems is summed up in the realization that the EBR-I, a 1-Mw experimental system, is the only unclassified sodium-cooled reactor that has been operated anywhere in the world to date.

However, the reactor programs of the United States and Great Britain should soon correct this situation. The Sodium Reactor Experiment, a joint venture by the AEC and North American Aviation, will go critical the first part of this year. The British have scheduled the start-up of the world's first fast power reactor at Dounreay, Scotland, in 1958. The EBR-II, the American counterpart of the Dounreay reactor, is to begin operation in 1959, and, finally, the EFFBR, the first large-scale fast power reactor, is planned for 1960. The considerable experience obtained in operating these large sodium systems should answer many of the questions about the feasibility of sodium technology in industry.

Fuel Inventory and Reprocessing

The fast-power-reactor concept also implies high fuel inventory and extra fuel-reprocessing costs. The critical mass of fissionable material of a fast reactor is larger than the mass of a comparable liquid-cooled thermal reactor by a factor of two or so. Since a large fuel inventory represents a large capital investment the material efficiency of a reactor (kw of electrical output per kg of fuel) is an important factor in determining the economic feasibility of a reactor. Although fast systems have high *thermal* efficiency they by nature have low *material* efficiency so that the over-all or "economic" efficiency of a fast system could easily be smaller than that of a water-cooled thermal system.

In addition the concentration of fissionable material in the meat of a fast-reactor fuel element is roughly 20% as compared with 1 or 2% for a thermal-reactor fuel element. Because of radiation damage, both kinds of elements would have to be removed from the reactor for reprocessing after not more than a number of fissionable atoms equal to about 2% of all the atoms (fissionable and nonfissionable) present have been burned up (*1*). This amount of burnup would consume almost all of the initial fuel charge in a thermal element (assuming enough breeding to keep the reactor critical) but not more than 10% of the initial fuel charge present in a fast-reactor element. Thus a fuel atom may have to be reprocessed more than 10 times before it is finally burned in a fast reactor.

These extra reprocessing operations will certainly add to the costs of operating a fast reactor directly, through the costs of the operations themselves and, indirectly, through the larger inventory requirement and fuel-loss charges associated with reprocessing.

On the other hand, unlike the thermal reactor the fast reactor is insensitive to fission-product poisons. Fuel burnup in a fast reactor is therefore limited more by radiation damage to the fuel than by available excess reactivity. Moreover the reprocessing need not remove all of the fission products and therefore can be much cruder. However, it seems unlikely that these advantages will outweigh the disadvantage of multiple reprocessing.

A possible way around this difficulty is being explored by the AEC in

the Los Alamos molten-plutonium reactor experiment. But this reactor concept has extreme design requirements and is regarded as something that may prove feasible only in the distant future. (See p. 67.)

At the present time the fast-reactor concept seems to be burdened with excessive fuel-reprocessing costs which may or may not be eventually eliminated. In any case the fast reactor will always be faced with the extra expenses associated with its large fuel inventory.

Safety

The recent Power Reactor Development Corp. (PRDC) hearings have served to focus attention on the question of the safety of fast-reactor systems. The EBR-I, the AEC's first experimental fast breeder, is the only fast reactor with which we have had extensive operational experience to date. It is a matter of record that during its recent operation the EBR (a) exhibited resonance instability, (b) showed definite evidence of a positive temperature coefficient, and (c) suffered a partial meltdown of its core during a power excursion.

It is easy to infer that these unpleasant traits are fundamental to all fast reactors. However, PRDC testimony refutes this guilt by association. In his testimony (*2*) Hans Bethe argued that the undesirable features of the EBR-I are not basic to fast-reactor designs and that a small amount of additional knowledge in this field would point the way to fast-reactor designs that are safe.

There are a number of characteristics peculiar, or sometimes believed to be peculiar, to fast reactors that are often cited by those who argue that this class of reactors is, in fact, inherently unsafe. They are cited here along with the counterarguments.

Short prompt lifetime. Perhaps the most conspicuous of these characteristics is that the prompt-neutron lifetime of the fast reactor is very short, at least a hundred times smaller than the prompt-neutron lifetime of a typical thermal reactor. Thus, if the reactivity ever exceeds prompt-critical, the power in a fast reactor will begin to rise with a period a hundred times faster than that in a thermal reactor.

Although the advocates of fast systems admit that the power excursion resulting from a prompt-critical reactivity would be much more severe for a fast reactor, they point out that the nature of fast reactors permits designs that make a prompt-critical situation very unlikely.

Because fast reactors are insensitive to fission-product poisons and have a large critical mass, the excess reactivity required to operate for a given number of megawatt days is much smaller for a fast reactor than for a thermal reactor. A large thermal power reactor requires an excess reactivity of the order of ten dollars. The needs of a comparable fast power reactor can be satisfied by an excess reactivity of less than one dollar, which is below the prompt-critical region. Thus, unlike thermal-reactor designs, the total amount of excess reactivity built into a fast reactor is less than the amount required to make the reactor go prompt-critical. Fast-reactor designers feel that under these circumstances it is difficult to imagine how a prompt-critical situation can arise without postulating a series of very unlikely events.

Even if by some unforeseen combination of circumstances the reactor should exceed prompt-critical, fast-reactor designers predict that nothing too serious would happen. NDA (Nuclear Development Corporation of America) has carried out calculations for APDA (Atomic Power Development Associates, Inc.) which show that even

Principles of Fast Breeders

A fast reactor is one in which the fission events are caused by fast neutrons—neutrons with energies close to 1 Mev. Thus, a fast-reactor designer must choose a configuration of materials that gives a neutron born in fission a good chance of being captured in fissionable material before it can either be captured elsewhere or be slowed down through scattering. The neutron cross section of materials in general (and of fissionable materials in particular) limit the design choice to one basic type—an enriched, unmoderated, core of fuel diluted as little as possible by other materials.

The absence of a hydrogenous moderator and the careful restriction of the amount and kind of materials used in the core are necessary to keep the neutron spectrum fast. Thus, the use of light elements in a fast-reactor core is always avoided. Structural and coolant materials should be held to a minimum since the addition to the core of any material other than fuel tends to soften the neutron spectrum. For instance, in going from the EBR-I (a fast experimental reactor) to the Enrico Fermi Fast Breeder Reactor (a power reactor) the average neutron energy is depressed from 0.5 Mev to 0.25 Mev by the addition to the core of materials necessary for cooling and breeding.

Since the fast-neutron fission cross section of U^{235} is only a few times greater than the absorption cross section of U^{238}, enriched fuel must be used to make a fast reactor critical. In addition, the fast reactor, to achieve criticality, needs a greater total amount of U^{235} than does a liquid-cooled thermal reactor. The reason is that the fast fission cross section of U^{235} is roughly 400 times smaller than its thermal fission cross section. Thus if the two kinds of reactors were to have the same core volume, the critical mass of U^{235} for the fast reactor would be many times larger than the critical mass of the thermal reactor.

However, a fast-reactor core will always be smaller than a thermal-reactor core producing the same total power. The fast-reactor core is smaller to begin with since it has no moderator component. In addition, the designer makes the core still smaller to reduce the critical mass and to keep the neutron spectrum fast. The first effect is purely geometrical; the second holds because a large core will be more diluted with nonfuel materials. The minimum practical core size is fixed by the amount of power per unit of core that can be tolerated from heat-transfer considerations.

It turns out that compared with a liquid-cooled thermal reactor of the same power the optimum fast reactor, although it has a much smaller core volume, still has a significantly larger critical mass. A fast reactor will then always operate at a higher power per unit volume of core and at a lower power per unit weight of invested fissionable material.

A primary reason for building fast power reactors is that breeding of U^{233} is only possible in a fast reactor. The breeding ratio (number of fissionable atoms created per fissionable atom destroyed) in a thermal reactor is less than 1.0 for the U^{235}-fuel–U^{238}-blanket and the Pu^{239}-fuel–U^{238}-blanket combinations.* The fast reactor has a breeding ratio near 1.2 for U^{235}-U^{238} and of at least 1.5 for Pu^{239}-U^{238}.

The fast-reactor breeding ratio is larger in general because of the smaller absorption of neutrons in structurals. For Pu^{239}-U^{238} and U^{233}-U^{238}, in particular, it is larger because of the fast fissions in U^{238} and the high value of α (ratio of the nonfission capture to fission cross sections in the fissionable isotope) for thermal neutrons in Pu^{239} and U^{233}.

To obtain the breeding ratios quoted above, the average energy of the neutrons in the fast reactor must be kept above 0.10 Mev. Below this energy the value of α increases rapidly, reducing the breeding gain. **(See figure on p. 63.)**

* It is true that the breeding ratio in a thermal reactor can be greater than 1.0 where U^{233} is the fuel and thorium is the fertile material but we are concerned here with U^{238}.

Strategies for Exploiting Our Atomic Resources

From a technical point of view there are two possible strategies that could be used to extract energy from the world's resources of uranium and thorium. One could use fast reactors exclusively or one could use mostly thermal reactors with a few fast reactors for breeding purposes. Economic feasibility will determine which scheme will eventually be used. It is too soon to say which system will ultimately prove superior. At the moment, however, for reasons presented elsewhere in this article thermal reactors seem to have the edge.

If the thermal machines do indeed win out, the atomic power industry may develop along the following lines: In the beginning all commercial power will be generated by thermal converters using U^{238} or thorium as raw materials. Since thermal reactors can breed successfully on a U^{233}-Th cycle and there would be presumably no economic advantage to using fast reactors for this purpose, thermal reactors alone will continue to be used to exploit thorium energy resources. Thorium deposits are believed to represent about half of the total atomic-energy potential; therefore on this basis, thermal thorium converters will account for roughly half of the reactor population. Thermal reactors converting natural uranium cannot breed and so require periodic additions of fissionable material. At first U^{235} obtained by enriching natural uranium will be used for this purpose.

Later on Pu produced by a fast reactor will become cheaper than U^{235} produced by enrichment. At this point the fast breeder will take over the function of supplying fissionable material to the uranium-converting thermal power reactors. The breeding ratio of the thermal converter is close enough to 1.0 so that a single fast breeder can supply a number of thermal reactors. Thus if the converter has a breeding ratio of 0.9 and the fast reactor has a ratio of 1.5 the fast reactor can keep five thermal converters in business, each at a power level equal to that of the fast reactor. Thus the primary function of a fast-breeder power reactor of the future will be to feed fissionable material to thermal reactors which in turn will generate practically all the power.

In this way the total energy available in the world's resources of U^{235} can be completely utilized. Although in such a scheme the number of fast reactors would be in the minority, their presence is absolutely essential. Without them most of the energy stored in U^{238} would be inaccessible. For this reason, regardless of which reactor type proves more economical, the development of satisfactory fast breeder power reactors is a job which must be done.

under quite pessimistic conditions the total energy released during a prompt-critical power surge would probably not be enough to rupture the reactor vessel.

Moderator accident. Another characteristic of fast reactors that might influence safety is that the reactivity of a fast reactor will increase if a moderator is somehow introduced into the system. For instance, if the sodium in a fast-reactor coolant system were partially replaced by some material containing hydrogen—say oil or water—the reactivity would increase and might conceivably go beyond prompt-critical. Designers believe, however, that fast-reactor systems can be constructed in ways that will eliminate this possibility.

The EFFBR designers, for instance, have severely restricted the use of hydrogenous materials anywhere in the building. Since it is difficult to see how even the small amount of material that will be available could get into the sodium system, the EFFBR designers believe that for their machine the moderator hazard is negligible.

Positive temperature coefficient. The observation that the EBR-I had a prompt positive temperature coefficient is sometimes interpreted to mean that all fast reactors will have prompt positive temperature coefficients. Those familiar with the physics and the history of the EBR-I believe that the opposite is true. They contend that the observed positive coefficient most likely originates from the bowing of the fuel elements caused by radial temperature gradients present during reactor operation. One can estimate the amount of bowing that should occur at a given reactor power, and this turns out to be about the right amount to explain the observed temperature coefficient. Since no one can suggest any alternative effects to explain the observations,* it is generally believed that bowing was the sole cause of the EBR-I positive temperature coefficient. Such an effect clearly depends on particular details of the core design and has nothing to do with characteristics of fast reactors in general.

Resonance instability. The EBR-I experiments also revealed another, less well known type of instability, called resonance instability. This kind of reactor instability is characterized by spontaneous oscillations of the reactor power at certain discrete reactor operating conditions. Again, since experience with this kind of behavior is limited to the EBR-I, there has been a tendency to associate resonance instability with fast reactors. However, recent studies indicate that the resonant behavior of the EBR-I, like the positive temperature coefficient, is caused by specific design features and would not be a general characteristic of fast reactors.

In general, resonance behavior of a physical system depends on the existence of a feed-back relationship between two dynamic variables associated with the system. In a reactor the power influences the reactivity, and the reactivity in turn determines the power so that these two variables form a feed-back loop. Because of this feed-back mechanism reactor systems may have resonances at certain well-defined operating conditions—when the reactor is operated at certain combinations of power level and coolant flow, the reactor power will begin to oscillate at a definite frequency without any external cause. If the reactor power is increased beyond the resonance value the amplitude of the power oscillations will increase exponentially with time. The reactor would then be intrinsically unstable in this region. However, the reactor would be completely safe as long as its power level is kept below the resonance value.

Bethe incorporated in his PRDC testimony a thorough analysis of the theory and detection of resonances in reactor systems (*3*). He concludes that a reactor resonance always requires the existence of a large delayed negative temperature coefficient of reactivity. Such coefficients would probably be associated with the heating of structural components outside the core by convection. Bethe points out that this kind of difficulty would be hard to foresee in the design stage and might not be uncovered until the reactor is built and tested. (For instance, no one has yet explained the physical origin of a delayed negative temperature coefficient in the EBR-I.)

Because the existence of a delayed negative temperature coefficient depends on the details of the individual

* At one time the Doppler effect in the reactor fuel was considered as a possible source of a prompt positive temperature coefficient. However enough information is now available to discount this possibility. For the EBR-I at best only 5% of the observed positive temperature coefficient can be explained by Doppler effect. In a large power reactor like the EFFBR, because of the higher ratio of U^{238} to U^{235}, the Doppler effect will give a negative temperature coefficient.

reactor design, Bethe argues that resonances, in principle, could occur in either thermal or fast reactors. However, he also points out that the conditions for a resonance are more likely to be satisfied in an unmoderated small-core reactor than in a moderated large-core reactor. Since fast reactors generally fit the former description and thermal reactors the latter, resonances might be expected to crop up more frequently in fast systems.

Bethe feels confident that in either kind of reactor system resonances can be avoided by proper reactor design. Further observations planned by the AEC on EBR-I should provide valuable information for such designs.

Supercriticality upon meltdown. The final criticism of fast reactors is that the large amount of fissionable material contained in a fast-reactor core might through some accident redistribute itself to form a highly supercritical mass. For instance, if all the enriched material in the EFFBR were assembled in a solid ball and then surrounded by a good neutron reflector, the resulting mass would be six times critical.

This hazard is distinctly a characteristic of fast reactors. Thermal reactor fuel is always more diluted because of lower U^{235} enrichment or the presence of a moderator. In fast reactors, only the geometric dispersion of the fuel for cooling purposes prevents the reactor from being supercritical. For this reason, it is essential to make sure that the fuel in a fast reactor can never assemble in one large mass.

Such a situation might conceivably result if the core of the reactor were to melt during a severe power excursion. The fact that a partial meltdown did occur in the core of EBR-I (4) might lead to concern for the safety of all fast reactors in this respect.

Two important aspects of the EBR-I incident argue against this:

First, the meltdown accident occurred when the reactor was deliberately used in an unsafe way to test the positive temperature coefficient.

A full-scale power reactor would not have a positive temperature coefficient and would be designed so that operation under "experimental circumstances" would be impossible.

Second, the EBR-I meltdown did not result in the formation of a critical mass. Boiling sodium entrapped in the core is believed to have forced the molten uranium apart, preventing the formation of a critical mass. Apparently the melting of uranium in the presence of sodium, which can vaporize, does not lead to a supercritical assembly but tends instead to shut down the reactor.

The most serious potential hazard associated with a meltdown arises from a situation not present in the EBR-I incident. At the moment, as far as safety is concerned, the fast-reactor concept's biggest worry is the possibility that a supercritical meltdown might occur following the loss of the sodium coolant. Even if the reactor were immediately shut down with the safety rods, in the absence of coolant the fission-product afterheat would melt the core in a few minutes. Since there would be no sodium vapor to exert pressure, the molten core would collapse under gravity and might form a critical mass in the bottom of the reactor container.

Dr. Bethe and Dr. Tait of the British Atomic Research Establishment at Harwell, have made rough upper-limit calculations of the energy that might be released by such an accident. The most realistic value obtained so far is a total energy release equal to 1,000 lb of TNT. Although Bethe points out that this figure may be a gross overestimate, the magnitude of this result has stimulated a large effort to obtain more information.

The AEC has initiated a comprehensive program at Argonne designed to arrive at a basic understanding of meltdown phenomena. (See p. 67.)

In addition APDA has asked Nuclear Metals, Inc., Cambridge, Mass., to do experiments similar to those planned by ANL and has also undertaken further theoretical studies.

Meanwhile fast-reactor designers are trying very hard to minimize the chances of sodium-coolant loss and are also building in features to prevent a nuclear event if a coolant-loss meltdown should occur.

In the EFFBR secondary containment is provided around all primary-coolant-system piping and vessels so that a leak in the primary system cannot cause excessive loss of sodium. In the event of loss of pumping power the design allows sufficient natural-convection cooling for the decay heat. A large reservoir of sodium above the core appreciably increases the time required for a leak to drain the core. Other design provisions allow for direct emergency action to restore cooling if somehow the core were to be completely drained.

To limit the consequence of a meltdown a special meltdown container has been built into the lower sodium plenum. If a meltdown should occur the molten fuel is expected to collect in the container in a noncritical geometry. However, there is some concern that the molten fuel might refreeze in the coolant channels in the blanket region beneath the core and never reach the meltdown container. Depending on results of additional analysis PRDC may abandon the lower blanket in the interests of safety.

In summary, the question of fast-reactor safety is most likely one that can be eliminated by proper design. What constitutes proper design, however, is not yet completely understood.

Outlook

We may conclude that, as things stand today, the feasibility of the fast-reactor concept as a basic power producer suffers from both technical and economic difficulties. Hopefully, the purely technical problems may quickly be eliminated; the economic questions, however, are likely to remain.

The combined efforts of the AEC and PRDC can be expected to demonstrate in the near future that properly designed fast reactors are as safe to operate as thermal reactors. Also experience with the large sodium systems now being constructed may prove before long that the industrial use of sodium coolant is technically and even economically within reach. On the other hand, it is more doubtful that the fast reactor can escape the economic penalty of the extra fuel reprocessing. Higher expenses for core fabrication and fuel inventory appear to be permanent economic disadvantages.

In its favor the fast reactor has the one fundamental advantage of a breeding ratio substantially greater than 1.0. Thus, the value of the extra Pu produced by a fast breeder must exceed the additional expenses of building and operating a fast breeder if this kind of reactor is to compete with thermal reactors for the job of large-scale commercial power production.

BIBLIOGRAPHY

1. W. B. Lewis, NUCLEONICS **14,** No. 10, 28 (1956)
2. NUCLEONICS **15,** No. 2, R2 (1957)
3. H. A. Bethe. Reactor safety and oscillator tests, APDA-117 (1956)
4. NUCLEONICS **15,** No. 1, 84 (1957)

AEC's Fast-Reactor Program

SPEAKING FOR THE AEC at the PRDC hearing, W. Kenneth Davis, Director, Division of Reactor Development, USAEC, testified that the fast-reactor program is one of the AEC's major reactor development programs for civilian power. The six major aspects of the program are outlined below.

EBR-I

Experimental Breeder Reactor-I will be rebuilt with a new core, the Mark III, that can, by modification, be used either to minimize or emphasize thermal bowing of the fuel elements. Observations of the EBR-I under each of these conditions should determine whether bowing was the cause of the EBR-I prompt positive temperature coefficient with the Mark II core. EBR-I is scheduled to begin operation with the Mark III core August 1957. Temperature-coefficient and resonance-instability investigations will continue through to December 1958. Plans are being made to install a Mark IV core containing plutonium in early 1959. In 1960 EBR-I may be converted into a training facility for reactor engineers and operators.

EBR-II

EBR-II is a fast-breeder reactor of advanced design based upon experience gained from the EBR-I. It will operate at a thermal power level of 62.5 Mw, about 50 times the power level of EBR-I. Compared with the 300-Mw EFFBR (see p. 68), the EBR-II has higher performance and more advanced design features. The EBR-II then is intended to provide the basis for the design of full-scale reactors superior to EFFBR. In addition the program will emphasize investigations on ways to improve the reliability of large sodium systems. Construction will start in May 1957 and the reactor is to go critical June 1959.

Zero-Power Reactors

ZPR-III is a fast zero-power reactor at the National Reactor Testing Station in Idaho. It is used to mock up nuclear-core configurations for specific fast-power reactors. A comprehensive series of experiments has been undertaken on ZPR-III to determine the sign and magnitude of the Doppler effect in a fast reactor. Preliminary results indicate that the Doppler effect is smaller than anticipated and therefore could not have caused the positive temperature coefficient in EBR-I. ZPR-III is also used to furnish specific nuclear design data for EBR-II and EFFBR.

ZPR-V, located at Lemont, Illinois, is a coupled fast-neutron–thermal-neutron assembly that is being used to explore the feasibility of this concept for a power reactor. About 95% of the fissions in the reactor are caused by fast neutrons in the central region of the two-region core. The remaining 5% are caused by thermal neutrons in the outer-core region. The reactivity of the entire assembly is varied by controlling the thermals.

LAMPRE

The Los Alamos Molten Plutonium Reactor Experiment is an effort to determine the feasibility of building a fast power reactor that would use plutonium fuel in molten form. Such a reactor would be free of the reprocessing and fabrication problems connected with solid fuels. The use of molten fuels should also improve heat-transfer performance.

As presently planned, the program will be divided into three phases: the design, construction, and short-term operation of an experimental reactor, LAMPRE-I; the design, construction, and longer-term operation of a larger and more advanced reactor experiment, LAMPRE-II; and possibly the design, construction, and operation of an electrical power producing reactor, LAMPRE-III.

LAMPRE-I will operate at 1 Mw and will be sodium-cooled. A low-melting-point plutonium alloy will be contained in molten form in the spaces between the cooling tubes. The reactor should be critical in late 1958.

Reactor Meltdown

Argonne National Laboratory is making an effort to provide more information on a meltdown in the presence of sodium. Detailed observation of the Mark II core has provided the basis for a report to be issued in the near future that will reconstruct the sequence of events in the EBR-I meltdown. In addition ANL is planning experiments to observe the consequences of dropping molten uranium into liquid sodium. Preliminary data will be available July 1957.

A joint program between Los Alamos Scientific Laboratory and Argonne National Laboratory has been established to do a thorough theoretical analysis of the maximum credible accident that could result from a meltdown. Results good to within an order of magnitude are expected within a year.

Finally ANL has proposed the construction of a nuclear meltdown facility to determine precisely the mechanics of meltdown for specific types of fuel elements. The facility would be located at National Reactor Testing Station and would take an estimated 18 months to build.

Reactor Containment

Various organizations are pursuing under contracts with the AEC calculations and experiments on reactor containment. Naval Ordnance Laboratory at White Oak, Maryland, is investigating the general problem of adequate containment for both thermal and fast reactors of commercial size. NOL is using the design specifications of the EFFBR (see p. 68) for much of its work.

Further, the Ballistics Research Laboratory of Aberdeen Proving Ground is determining the important design criteria for containment vessels from the point of view of blast and shock phenomena. Armour Research Foundation is investigating shock-wave characteristics in an effort to design blast shields for reactors. Finally Oak Ridge National Laboratory is studying the distribution and characteristics of fission products which would be released in a serious nuclear reactor power excursion.

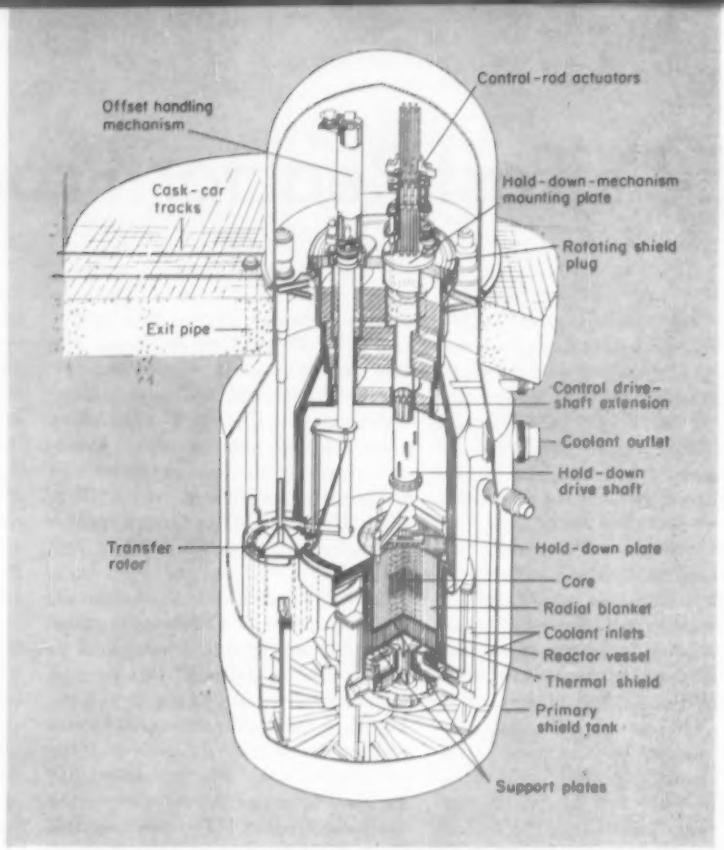


FIG. 1. Perspective drawing shows reactor in reactor vessel and primary-shield tank

Enrico Fermi Reactor

Design of First Fast Breeder

Neutron economy is the big advantage in this first full-scale power plant of its type. Flexibility will permit development toward reliable operation for practical power production

THE ENRICO FERMI Fast Breeder Reactor is designed to generate 300 Mw of heat and deliver a net output of 90 Mw of electric power. It is fueled with 27%-enriched uranium and will breed plutonium with a breeding ratio of 1.20. Heat is transferred from reactor to steam plant by primary and secondary sodium coolant circuits. Steam is developed at 755° F and 600 psig. The table on p. 70 lists significant characteristics of the various parts of the power plant. The plant is located ~30 miles southwest of Detroit at Lagoona Beach on Lake Erie and ~25 miles from Toledo (NU, Sept. 56, p. R3).

Core and Blanket

The core and blanket configuration can be seen in Fig. 1, which is a perspective view of the reactor. Core and blanket subassemblies having square cross sections are arranged to form a right circular cylinder 80 in. in diameter and 70 in. high. The core is completely surrounded by fertile material. There are four types of subassemblies containing different nuclear materials. All external dimensions are the same, but interchangeability is eliminated by making their support structures different. The numbers and types of subassemblies are as follows:

Type	*Number*	*Contents*
Core	91	U^{235}, U^{238}
Radial blanket	572	U^{238}
Thermal shield	198	Steel
Control	10	Boron-loaded rods

Figure 2 shows the arrangement of the assembly. The two shim control rods will be in the core during operation. Eight other rods are safety rods (Fig. 3). They will be suspended above the blanket during operation, and their places in the core will be filled with sodium.

The sodium coolant flows upward through the subassemblies. Of this flow 90% is directed through core

subassemblies, 7% through the radial blanket, and 2% past control rods. The remaining 1% of the flow is reserved for thermal-shield cooling and bypass leakage.

Subassemblies

Core subassemblies consist of upper and lower axial-blanket assemblies, each 18 in. long, and a 31-in. fuel section between them (Fig. 4). The fuel section holds 144 pins. Each is made by coextruding sponge zirconium and 10 wt-% U-Mo fuel alloy. A metallurgical bond between fuel and cladding is formed in the extrusion process. Final dimensions are obtained by cold swaging with intermediate anneals.

Axial-blanket elements have uranium pins in stainless-steel tubes. Sodium fills the intervening space and provides a low-resistance thermal bond. Allowance is made for increase in the length of the uranium due to thermal cycling and radiation damage.

Radial-blanket pins consist of stainless-steel tubes, each containing eight slugs of uranium, sodium for bonding, and 5 in. of space for growth of the uranium. Stainless-steel wire wrapped in spirals around the tubes maintains the spacing of the pins.

From the extrusion and swaging operation come pins 12 ft or more in length. These are cut into 30.5-in. sections that are pointed by swaging at one end and sealed at the other by welding on a preformed zirconium cap. The final step is heat treatment to promote radiation stability.

Performance

One design criterion is that the fuel alloy shall not exceed its melting point of 2,066° F even during an accidental excursion. This limits the value of steady-state fuel temperature to a maximum of 1,300° F. Dimensional irreversibility of alpha-beta phase transformations in unalloyed uranium caused by thermal cycling limits the maximum blanket temperature to 1,200° F. Furthermore the radial blanket is designed for maximum power conditions rather than the reference design condition for which the core is designed. If the power is increased, the core will be replaced, but the blanket will not.

Positioning. Subassemblies are held in position by the support plates and the hold-down plate shown in Fig. 1. The hold-down plate has a recessed knob for the handling head of each subassembly. As the plate is lowered into position, pressure on the handling head forces the subassembly down and compresses the spring at the bottom of the subassembly (Fig. 4). Thus the hold-down plate holds the subassembly against the force exerted by coolant flow, and the compressed spring holds it against the plate.

Handling Subassemblies

Refueling and transfer of radial-blanket subassemblies are accomplished

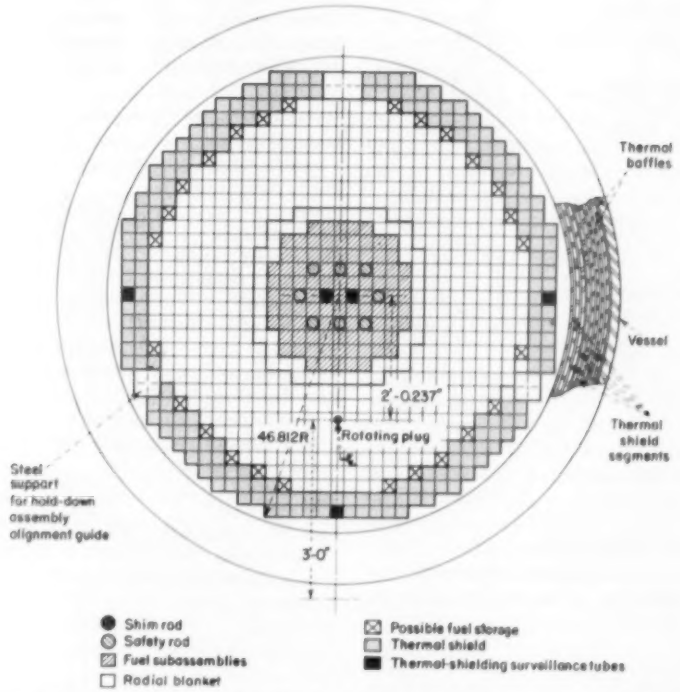


FIG. 2. Reactor configuration is made up of 4 kinds of subassemblies having same outside dimensions, different fittings and loadings

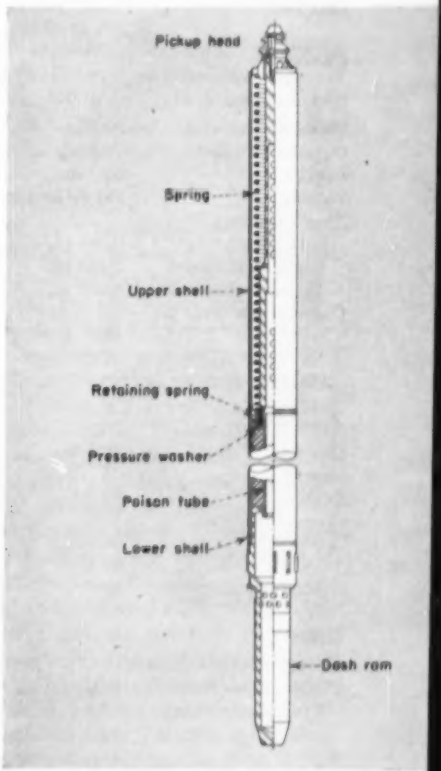


FIG. 3. Control rod: dash ram, poison section, extension rod, and pickup head

Characteristics of the Enrico Fermi Fast Breeder

Over-All

Power	
Thermal	300 Mw
Electric (gross)	100 Mw
(net)	90 Mw
Critical *mass*, U^{235}	485 kg
Breeding ratio	1.20
Primary and secondary coolants	Na
Temperature coefficient ($\Delta k/k/°$ C)	-24.0×10^{-6}

Core

Length	31.2 in.
Diameter	30.5 in.
Volume	11.65 ft³
Specific power	553 kw/kg U^{235}
Composition (vol %)	
U^{235}	7.75
U^{238}	21.35
Zr, Mo, ss	24.7
Na	46.2
Fuel subassemblies	91
Pins per assembly	144
Fuel cladding	Zr
Max fuel temperature	1,300° F

Blanket

Radial section	
Inside diameter	30.5 in.
Outside diameter	78.5 in.
Length	67 in.
Volume	161 ft³
Pin dimensions	
O.D. (clad)	0.443 in.
Uranium diameter	0.415 in.
Na bond thickness	0.004 in.
Composition (vol. %)	
U^{238}	46.7
Na	34.0
Stainless steel	19.3
Axial section	
Diameter	30.5 in.
Length	18 in.
Volume	13 ft³
Composition (vol. %)	
U^{238}	46.7
Na	47.3
Stainless steel	16.6

Control

Δk requirements (dollars*)	
Max excess reactivity	0.92
Variable reactivity supplied by controls	8.92
Safety rods	
Number	8
Reactivity/rod	$1.00
Poison length	33 in.
Rod cross section	4 in.²
Weight, each rod	50 lb
Max run-in	$0.75/sec
Scram rate	$25/sec
Removal time (8 rods)	27 min
Shim control rods	
Number	2
Reactivity (both)	$0.92

Physics

Average effective core flux	0.5×10^{15} n/cm²/sec
Average core neutron energy	0.25 Mev
Prompt-neutron lifetime	0.2 μsec
Max/average core power	
Axial variation	1.32
Radial variation	1.21
Over-all	1.60
Blanket power/total power	0.074

Vessels

Reactor vessel	
Material	304 ss
Height	35 ft
Max diameter	14.5 ft
Max thickness	2 in.
Empty weight	580,000 lb
Primary shield tank	
Material	ASTM A-285 GrC carbon steel
Height	39 ft
Max diameter	24 ft
Empty weight	178,000 lb
Containment vessel	
Material	ASTM A-201 GrB carbon steel
Height	120 ft
Inside diameter	72 ft
Max thickness	1.06 in.

Primary coolant system

Total weight of sodium	274,000 lb
Temperatures at intermediate heat exchanger	
Inlet	800° F
Outlet	550° F
Total flow	13.2×10^6 lb/hr (= 30,000 gpm at pump temperature)
Total pressure drop	92 psi
Piping	
Material	304 stainless steel
Diameter (pump system †)	30 in.
Wall thickness (pump system)	⅜ in.
Design pressure	125 psig
Design temperature	1,000° F
Average fluid velocity (pump system)	4.8 ft/sec

Secondary coolant system

Total weight of sodium	111,000 lb
Temperatures at intermediate heat exchanger	
Inlet	515° F
Outlet	765° F
Total flow	13.2×10^6 lb/hr
Total pressure drop	18 psi
Piping	
Material	304 stainless steel
Diameter	16 in.
Wall thickness	⅜ in.
Design pressure	300 psig
Design temperature	1,000° F
Average fluid velocity	18 fps

Steam power-generating systems

Material (tubes, headers, shell)	304 stainless steel
Steam generating capacity	339,000 lb/hr
Steam pressure	600 psig
Steam temperature	755° F
Feedwater temperature (entering)	400° F
Heat transfer (Btu/hr)	
Total	341.3×10^6
Superheater	60.6×10^6
Heat flux (Btu/hr/ft²)	
Feed heater	39,100
1st evaporating section	127,000
2nd evaporating section	161,000
Superheater	15,400
Log mean temperature difference	
Feed heater	80
1st evaporating section	104
2nd evaporating section	206
Superheater	71.4

* A dollar is that amount of excess reactivity that would make the reactor prompt critical. For the Enrico Fermi Reactor 1 dollar = 0.75%.

† Pump-to-reactor piping system has 16-in. pipes for 100% flow, 14-in. pipes for 90% flow, and 6-in. pipes for 10% flow.

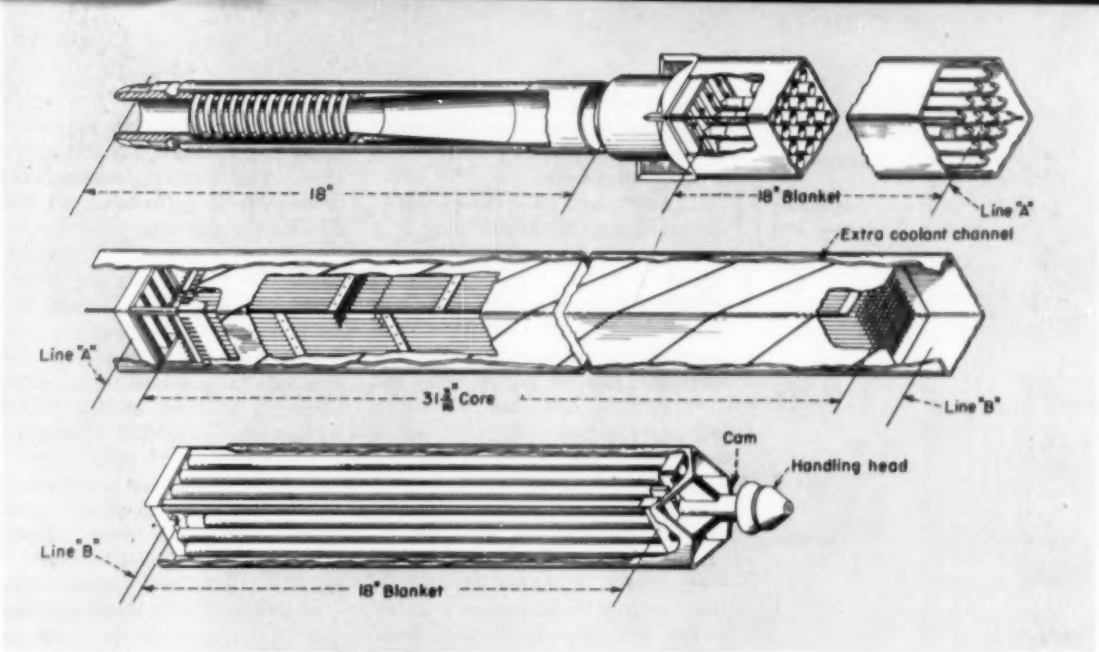


FIG. 4. Core subassembly has fuel pins at center and axial blanket pins at each end

during shutdown by means of remotely operated equipment that can be seen in Fig. 1. Shutdown time for fuel loading will require 10–20 hr/wk. The reactor will be charged weekly, fortnightly, or monthly, depending on analysis of actual operating economics. Blanket subassemblies will be changed less frequently and in groups of about 180.

Rotation of the rotating shield plug about the central axis of the reactor and of the offset handling mechanism about its own axis will place the gripper of the handling mechanism over any subassembly in the reactor. The subassembly is then moved to an empty pot in the rotor.

After a cooling period the finned pot with its subassembly is pulled up through the exit pipe into a cask car that rolls on the tracks shown in Fig. 1. The cask car replaces the pots it removes from the transfer rotor with others that carry fresh subassemblies from plant storage. The fresh assemblies are then transferred from the rotor to the proper position in the core or blanket.

The transfer rotor provides storage space in sodium during the period immediately after removal from the reactor. Subassemblies will remain in the rotor between transfer periods. Provision is also made for storage of 26 core subassemblies in the outer edge of the radial blanket as shown in Fig. 2. The cask car has its own inert-gas cooling system to remove heat from the finned pots when they are lifted from the rotor.

The steps required in a complete loading cycle are as follows:

1. Reduce power to zero.
2. Reduce sodium flow.
3. Detach control rods.
4. Raise hold-down device.
5. Raise control-rod actuators.
6. Lift a subassembly in storage in transfer rotor up into the cask car.
7. Replace the subassembly that is removed with a fresh one.
8. Transfer a subassembly from the core or radial blanket to the empty position in the rotor.
9. Withdraw the handling mechanism and rotate the rotor to place the next fresh subassembly under the pickup grippers.
10. Transfer the fresh subassembly to the empty reactor position.

Coolant Flow

Coolant flows into the high-pressure plenum through three 14-in. nozzles at 110 psi. It flows up through the square opening in the support structure to the subassemblies in the core and the first row of the radial blanket. More coolant is supplied at 20 psi through three 6-in. nozzles to the support-structure manifold and flows up through thermal-shielding and radial-blanket assemblies.

A removable orifice in the lower support plate will maintain proper flow in control-rod guide tubes and thermal shielding. Orifices can be added to fuel-subassembly inlets if desirable.

Primary coolant will be kept as free as possible of foreign particles, including sodium oxide. Before start-up the sodium will be bypassed through filters. In operation some of it will be bypassed through a cold trap for oxide removal.

The oxide concentration will be well below the saturation point at the system's lowest temperature. Even if a deposit were to occur, it would not be in the fuel-element channels but rather in the intermediate heat exchanger or in the inlet piping.

It is possible that during operation parts of the primary-system loop will erode. The bypass cold-trap circuit, which contains a filter, will remove corrosion particles.

Control

In Fig. 2 can be seen the positions of eight safety rods and two shim rods that control the reactor. The safety rods will be entirely withdrawn during operation and will serve only to shut the reactor down quickly and hold it well below critical during shutdown. The shim rods will control power level.

Safety rods. Figure 3 shows one of the safety rods, which consists of four sections: dashpot ram, poison section, extension rod, and pickup head. When it is picked up, a sleeve extending down from the pickup mechanism will compress the accelerating spring, and then the mechanism will grab the pickup head by means of an electromagnet-operated latch. Failure of the magnet current allows the rod to be released, and it is accelerated into the shutdown position by the spring.

The poison has the length of the core and consists of hollow cylinders of boron carbide enriched in B^{10}, which has a high cross section for an n,α reaction

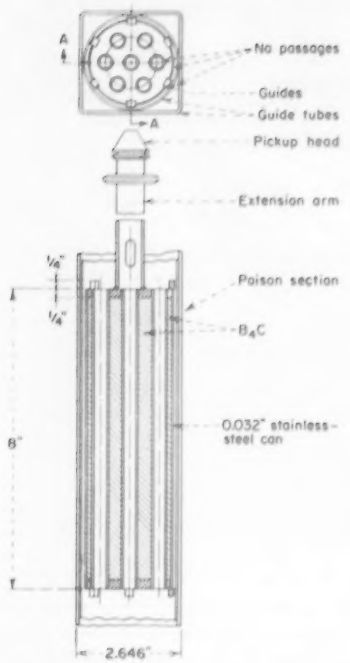


FIG. 5. Shim rod has 7 steel-lined coolant channels through boron carbide

with fast neutrons. A porous stainless-steel tube inside the cylinder of boron carbide conducts sodium coolant. Its pores permit sodium to pass into the boron carbide for good thermal bonding, permit helium formed in the n,α reaction to escape into the sodium stream, but do not allow passage of any of the boron carbide.

The safety rods have three types of vertical motion: (a) Motor drive by a 3-phase reversible induction motor through a rack and pinion will raise and lower the rods at 2 in./min. (b) Controlled rundown of drive shaft and rod under the influence of gravity will lower the rods at 2.5 in./sec. The drive motor is disconnected from its gearing by a magnetic clutch, and a centrifugal brake, geared to the rack, limits the rundown speed. (c) Spring-activated acceleration into the core at an average velocity of 100 in./sec occurs when a scram signal is received.

Shim rods. Three sections make up the shim rods shown in Fig. 5: poison section, extension rod, and pickup head. Five holes parallel to the axis and lined with porous stainless steel pass sodium coolant as in the safety rods. The shim rods have only one type of motion, a motor drive through a rack and pinion at a rate of 8 in./min.

Auxiliary safety control. Primary safety is not operational during reloading, for all control rods are disconnected and inserted fully into the core. To make insertion of excess reactivity in the form of fuel impossible, a quick reverse is provided in the subassembly-handling mechanism. Two 200-curie antimony-beryllium neutron sources provide neutrons to ensure that the safety instrumentation is always operative. The 10-in.-long sources will be in the shim-rod guide tubes just below the center of the core.

Shielding

The following design criteria have been adopted for shielding:

1. Biological shielding limits the dose rate to personnel to $\frac{1}{16}$ of that allowed in AEC installations for 40-hr/wk exposure. The AEC-allowed rate is 300 mr/wk.

2. Areas that are not open to people but in which the secondary coolant must be prevented from activating equipment are shielded to reduce the neutron flux to 10^4 n/cm²/sec.

3. Through its life the reactor vessel will be exposed to no more than 10^{22} n/cm². This limits the high-energy neutron flux to 3×10^{13} n/cm²/sec.

4. To limit heating and loss of water in concrete shields, temperatures of concrete will be kept below 200° F and the incident flux of neutrons and gammas on concrete surfaces will be kept below 4×10^{10} Mev/cm²/sec.

Figure 6 indicates the layout of the shielding. It can be generally divided into the primary shield in the primary shield tank, the secondary concrete shield around the primary shield tank, and the biological shield that forms the operating floor and surrounds the containment vessel.

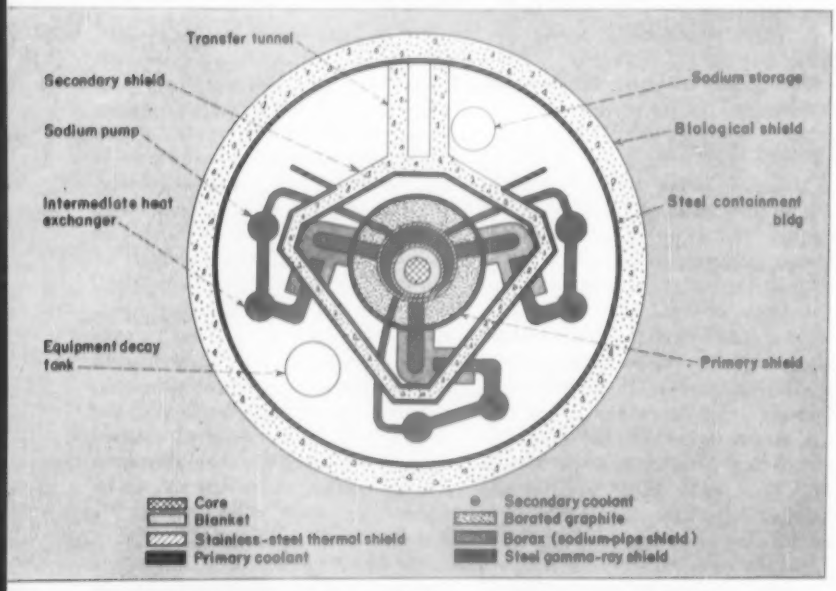


FIG. 6. Shielding is arranged to divide reactor into three compartments

Containment Vessel

The steel reactor building or containment vessel is designed to contain all radioactive fission products or radioactive sodium released by any incident. It is a vertical cylinder with hemispherical top and ellipsoidal bottom. Inside diameter is 72 ft, and over-all height is 120 ft. Walls will be $1\frac{1}{16}$ in. of ASTM A-201 Firebox-quality Grade B steel. Design conditions are as follows:

Steady-state pressure	
Positive	32 psig
Negative	5
Steel temperature	650° F

Personnel access is through an air lock with interlocks to prevent simultaneous opening of its doors. There is also a small emergency air lock. Equipment passes through a larger door interlocked to prevent opening during operation or loading.

Pressurized-Water Test Loop at MTR

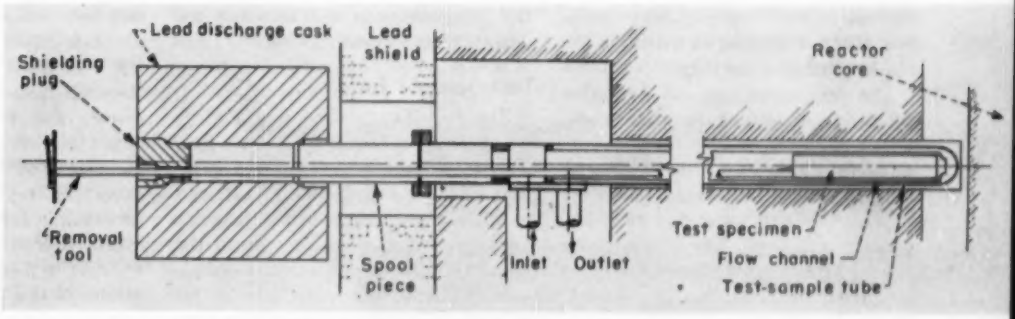


FIG. 1. In-pile section of test loop is shown along with removal tool and discharge cask

60 gpm of reactor-grade water at 1,500 psi and 500° F flow past test samples in a thermal flux of 2.5 × 10^{14} n/cm^2/sec in Argonne's loop for in-pile testing of reactor materials

By EMIL L. MARTINEC
Argonne National Laboratory, Lemont, Illinois

MEANINGFUL TESTS of the effect of radiation upon fuel elements and structural materials can only be made by irradiating those materials under conditions that approximate those encountered in actual reactor operation. To provide these conditions, the Argonne National Laboratory has constructed a high-pressure water loop in the Materials Testing Reactor.

The Argonne high-pressure water loop, known as ANL-2, was designed by the staff of the Reactor Engineering Division under the leadership of L. W. Fromm and H. Monson. It was first started up in the early part of 1954 and has been operating since that time.

The testing of a fuel specimen under irradiation in the ANL-2 water loop is final proof of a new element prototype design. Usually the specimens have been proved satisfactory in all aspects during out-of-pile tests. The results of the in-pile proof test will indicate whether the specimen is satisfactory for a fuel-element design.

The method of testing fuel-element and structural materials in a high-pressure, high-temperature water loop and under irradiation and simulated normal operating conditions is one of the best we have used to date. Fuel-element design prototypes which have been satisfactorily tested in our high-pressure water loop are now being used in our present reactor construction.

Design Considerations

Among the problems to be considered in the design of a high-pressure water loop are gamma heating and radiation damage of the in-pile portion of the loop. The thermal stresses caused by the high gamma heat require rigid design analysis. Radiation damage to the tube material also requires careful examination. Radiation exposure can cause materials to become brittle and lower their tensile strength. In some cases the combination of gamma heating and radiation damage can cause a designer to reduce the size of the in-pile portion considerably below that allowed by the reactor facility.

Another major problem in designing the test loop is to provide adequate controls to operate the loop automatically both normally and in the event an emergency condition should arise. The optimum in automatic control design for test loops would be an installation of a sequence timer that would have complete control of normal loop operation, requiring only one person to punch the start button.

Since the loop flow rate was to be

40–80 gpm, a flow of 60 gpm was used as a design basis for obtaining the necessary water velocity past the test specimens. The velocity depends on the design of the specimens and specimen holders. If a particular design does not give the desired velocity, the design is usually altered, although slight variations in the flow can be made. A flow rate of 60 gpm is maintained to allow for a decrease in the flow due to corrosion-product buildup and also to maintain adequate cooling at the tip of the in-pile portion of the loop.

The test specimens can be either cylindrical or rectangular in cross section. Specimen holders can be designed to accomodate either type with the only limit on size being that the free area should be sufficient to permit adequate water flow. The length of the specimens is limited by the fall off of flux along the centerline of the specimen. This length is usually held to ~15 in. to avoid an excessive flux differential.

The maximum rate of heat generation that can be permitted in all specimens within the in-pile portion of the loop is 100 kw (this includes both gamma and fission heating). Actually the rate of heat generation rarely exceeds 50 kw in any experiment, since it is difficult to obtain much more than this rate from the number of specimens that can be fitted into a single specimen holder. A calculated heat-transfer rate of ~500,000 btu/hr/ft² is considered more than adequate for the prevailing heat-transfer conditions, which are limited by the loop water pump capacity, the maximum system pressure, and the available heat-transfer surface.

FUNCTIONAL DESCRIPTION

The Argonne high-pressure water loop was built to circulate water at a pressure of 1,500 psi and a temperature of 500° F past two sets of samples. One, the test sample, is located in a tube mounted in horizontal beam hole HB-2 of the MTR. The other, the control sample, is located in an external tube. The HB-2 horizontal beam hole extends through the reactor tank to within 2 in. of the core face at the horizontal centerline of the core and has a maximum thermal neutron flux of 2.5×10^{14} n/cm²/sec. The control sample receives the same environment as the test sample except for exposure to the neutron and gamma flux. The circulating water flows past both samples, first through the in-pile tube and then through the external tube. The entire loop is constructed of 300 series stainless steels to minimize the effects of corrosion.

The equipment required to maintain circulation in the loop at the desired operating conditions is located within a cubicle in the basement of the reactor building to minimize the radiation hazard. A brief functional description of the components of the loop and the operating equipment follows.

Test-Sample Tube

The test-sample tube (see Fig. 1) holds the specimen in the reactor flux. The test sample is mounted in a specimen holder and the holder is positioned in the reactor-core end of a rectangular test-section tube that runs down the center of the cylindrical test-sample tube. The cooling water flows in toward the reactor core through the test-section tube, past the specimen in the end of the test-sample tube, is reversed in direction by a hemispherical cap at the tip of the test-sample tube, and returns through the annulus between the test-section tube and the test-sample tube.

The maximum operating pressure for the test-sample tube is limited by the total stress in the tube wall produced by the internal pressure of the water and the gamma heating of the tube wall. The critical portion of the tube is the hemispherical cap for gamma heating is greatest there. The tube tip was designed to permit operation at water conditions of 1,500 psi and 500° F with a maximum gamma heating of 11 watt/gm. In the construction of a reactor, the high value for gamma heating is cut down by thermal shields which are placed adjacent to the core to reduce the gamma heating in the load or pressure bearing members of the reactor. In the water loop, however, it is not feasible to put thermal shields around the test-sample tube because they would reduce the flux in the test samples.

An exhaustive stress analysis* was made of the tube-tip design to insure that the design adequately conformed to the requirements of the ASME and ASA codes. The analysis indicated that the maximum membrane stress at an internal pressure and temperature of 1,650 psi and 600° F are well below the allowable membrane stresses. The sum of the membrane and thermal stresses at points of maximum stress is 24,930 psi, which is well below the maximum allowable combined membrane and bending stress of 25,575 psi.

Before the maximum desirable loop operating conditions of 2,250 psi and 625° F can be reached, a new test-sample tube must be designed. Such a new tube would probably be of smaller diameter and incorporate external cooling. A tube recently examined at Argonne has been subjected to a greater fast flux, 10^{21} neutron, than any other stainless-steel load-bearing member that has been examined to date. The replacement for the present test-sample tube will have a fast flux exposure of approximately 2.0×10^{21} when it is placed in the loop in September of this year.

Control-Sample Tube

The external tube which holds the control sample is identical to the test-sample tube, except that it is shorter in length. The control sample is contained in the same environment as the test sample except for the neutron and gamma flux.

Specimen-Removal Tool

When a specimen is to be removed from the test-sample tube, the in-pile piping is isolated from the remainder of the system by closing the isolation valves. The in-pile system is then drained and blown out with air. The blind flange is removed from the end of the test-sample tube, and a lead cask is rolled up to it. A special tool (also shown in Fig. 2) is used for removing the specimen. This tool is approximately 20 ft long and has a latching mechanism at the end. The latching mechanism incorporates a means of making positive contact with the specimen, which cannot be withdrawn from the tube unless the latching mechanism has locked on it. After the specimen is withdrawn into the cask, the tool is removed, and plugs are then inserted into the ends of the cask.

The out-of-pile specimen is withdrawn with the same type of tool except that this tool is only 4 ft long. The out-of-pile specimens are not as radioactive as those in the test-sample tube and therefore can be withdrawn into a length of pipe instead of a lead cask. The out-of-pile specimens have not

* L. W. Fromm, Design Evaluation of In-Reactor Tube for Argonne Water Loop at MTR (ANL-2), ANL-5403 (1955).

been irradiated, the only activity coming from radioactive corrosion products which coat the element surface.

The insertion of specimens in the tubes is accomplished in the reverse manner by using the same tools.

Pumps

The three water pumps (see Fig. 3) are used in the Argonne loop. The pumps are oil-cooled canned-rotor pumps manufactured by Westinghouse Electric Corp. These pumps are set up in parallel with one normally operating and the other two acting as standby pumps.

Two standby pumps are provided to insure the safety of the equipment. If the system included only one standby pump, the situation wherein the operating pump failed would require lowering the operating temperature of the water because, if the temperature were not reduced under these conditions and the remaining pump should fail, boiling would be initiated in the test-sample tube tip and the line heater section of the loop. Although upon failure of the remaining pump the reactor would be scrammed, enough residual heat would remain to cause possible burnout conditions to exist.

The pumps are electrically interconnected by a relay system that automatically produces a switchover from the normally operating pump to a standby pump in the case of a pump failure or a low-flow condition. If for some reason the first standby pump does not start or resume normal flow, a switchover to the second pump is initiated.

Heaters

Clamped to the surface of an especially machined section of the loop are clamshell-type electrical heaters. These heaters can furnish up to 30 kw of heat to the system. Although there is 36 kw available, the heater output is limited to 30 kw to maintain reserve power for use in the event of the loss of a section of the line heaters. The heat can be added at a controllable rate so as to maintain the desired circulating water temperature. The clamp-on-type heater was preferred to the immersion-type because contamination due to a leak in the immersion heater would not be desirable. An additional line heater section is included in the loop which will produce 24 kw of heat for maintaining the circulating water at an elevated temperature during reactor shutdown periods.

Heat Exchanger

A water-to-air heat exchanger is installed in the loop with ducting to the MTR stack. The heat exchanger is incorporated as a safeguard since, under normal circumstances, there is enough heat loss from the external piping of the loop to compensate for gamma heating of the test-sample tube and the small amounts of heat generated in the specimens. The heat exchanger is a single-pass type consisting of type 347 stainless-steel tubes in parallel. It has a heat-transfer area of 60 sq ft and a heat-removal capacity of ~100 kw. Four dampers are provided to control the air flow through the exchanger. Two main dampers are located at the bottom and at the top of the exchanger, with one in the stack ducting, and the fourth in a bypass duct which is provided to minimize the amount of air seepage past the main dampers when they are closed. The bypass duct damper is always open, except during an emergency cooldown, to vent the loop cubicle. This type of exchanger was selected mainly because no pumps or blowers are required which might stop as a result of an electrical failure.

Surge Tank

A surge tank compensates for volume changes during heating or cooling of the system and provides and maintains the desired system pressure. The cast stainless-steel surge tank holds ~40 gal of water. It has a diameter of 12¾ in., and a wall thickness of 1½ in. The surge tank was designed to withstand a pressure of 2,250 psi at a temperature of 625° F. The surge tank heaters are clamped to four pipe legs which extend from the sides of the tank and re-enter at the bottom. The heaters are of the same type as those used for the line heaters. This method of heating the surge-tank water was provided because of the high thermal stresses encountered in attempting to heat the vessel itself.

Ion Exchanger

An ion exchanger, bypass type, is provided for the control of water purity in the loop. A portion of the circulating water is diverted from the loop to the ion exchanger resin bed. The water passes through a regenerative cooler, a water cooler, and a micrometallic filter before entering the ion exchanger. The entering water is cooled down to a temperature of ~90° F in order to prevent damage to the resin. The water leaving the column passes through a micrometallic filter and the reheater before being returned to the loop. Conductivity cells are placed before and after the ion exchanger column to measure its efficiency.

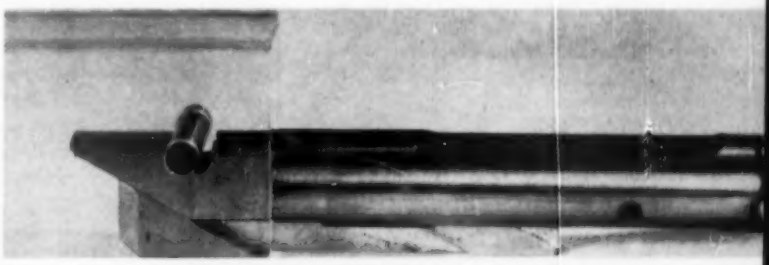


FIG. 2. Removal tool latching onto test-specimen mock-up

Degassifier

A bypass degassifier is provided for controlling the concentration of dissolved gases in the circulating water. A portion of the water is taken from the loop and is fed into degassifier trays which are located in the vapor phase of the surge tank. The gas is removed from the water by the scrubbing action of the steam as the water passes through the degassifier trays. The degassed water is then returned to the circulating system through the pressure equalizing line from the surge tank to the system.

Filters, Relief Valves

In addition to the ion exchanger, there are a series of full-flow filters and particle collectors which aid in eliminating foreign particles and corrosion

products from the circulating water.

There are three filters in the loop, one at the inlet to the pumps to protect the operating pump, and two in the discharge manifold of the pumps to protect the loop in the event of a pump bearing failure.

The two particle collectors are simply stagnant legs in the piping in which the precipitation of large particles will occur.

There are four relief valves in the loop. They are located on the surge tank to provide protection in the event of a failure of the automatic control circuit which governs high pressure, on the test-sample tube piping to provide protection in the event this portion of the system is isolated from the remainder of the system and there is sufficient heat generation in the test-sample tube to cause excessive pressure, on the makeup tank to provide protection in the event of failure of the heater's controls, and on the makeup pump to prevent excessive pressures if the pump is operated while the discharge valves are closed.

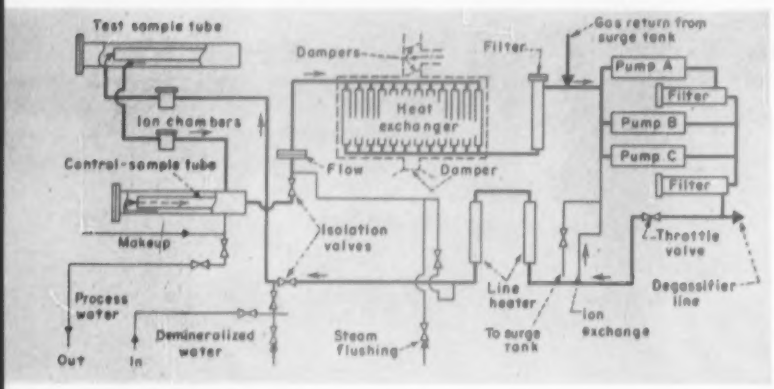


FIG. 3. Flow diagram of water loop

Auxiliary Equipment

The auxiliary equipment which is required to keep the loop in operation comprise a makeup system, a water sampling system, an emergency cooling system, and a pump cooling system.

Makeup system. The makeup system is required to make purified water available for addition to the loop. Demineralized water is used to fill the makeup tank, where it is heated to 300° F and then degassed by blowing off about 10% of the water. A deoxygenating system was recently installed on the loop for deoxygenating the demineralized water before it is added to the loop. The system consists of two resin beds and a conductivity cell. The first bed is a sulfite deoxygenating resin and the second bed is an MB-1 type ion exchange resin. The condition of the ion exchange resin bed is monitored by the conductivity cell. The effectiveness of the deoxygenating resin is checked periodically by performing an oxygen analysis of the makeup water.

The makeup tanks holds ~100 gal of water and is steam heated. It has sufficient capacity to fill the entire loop with degassed water. The steam from degassing the makeup water is used for steam flushing prior to filling the loop to eliminate as much air as possible from the system.

The makeup water is injected into the system by a small Milton Roy Co. high-pressure piston-type pump. This pump is capable of delivering 210 gpm of water at 2,500 psi. The pump is also used to pressure-test the loop.

Water-sampling system. The sampling system provides a place in which to obtain water samples from various points in the loop such as the pump inlet, test-sample tube inlet, surge tank bottom, ion exchanger column, etc. All of the sample lines which will contain water over 200° F while the loop is in operation run through a small cooler before entering a sample station. Any test or measurements which are performed in the sample station must be done at atmospheric conditions. If high-pressure and -temperature samples are desired, they are taken in a special high-pressure sample bomb. Water is circulated through the bomb by using the differential pressure obtained from sample points at the pump suction and discharge.

Emergency cooling system. Provisions are made in the loop for the switchover to process-water circulation in the event that normal circulation of water through the loop is stopped. Water flow past the test sample is required at all times when the reactor is at power to prevent burnout of the sample and the tube. The process water is the water that flows through the active lattice and other parts of the reactor that require water cooling. Since process water is not of very high purity, it would be used only in an emergency, for it may have undesirable effects upon the sample being tested and would accelerate the process of corrosion in the tube. The switchover to process water must be performed while the reactor is shut down. The switchover is made by closing the isolation valves, which isolate the in-pile portion from the remainder of the loop, and opening the process water entry and return valves. The process-water flow is automatically controlled by an air-operated valve which is controlled from the loop panel board.

Pump cooling system. A cooling-oil system provides the necessary coolant for the three water pumps. There are two oil pumps in the system, one operating and one standby. The pumps are electrically interconnected by a relay system which automatically switches from the normally operating pump to the standby pump in the event of a pump failure or low-flow condition. The oil flow returns from the water pump, enters a small single-pass cooler where the heat is removed, and then flows to an oil sump. The oil pumps have a maximum capacity of 35 gpm. A bypass-type oil filter system has been installed to remove foreign particles from the oil.

Instrumentation

The instrumentation of the loop was designed with three specific objectives in mind. These objectives were to protect the reactor at all times from damage, to control the loop as automatically as possible, and to provide indication or recording of all necessary data.

The instrument panels contain instruments for the control, measurement, and monitoring of pressure, tem-

perature, flow, surge tank level, water activity and saturation.

Pressure control. The loop pressure is maintained by the steam pressure formed in the surge tank. The head of steam is formed by the 24-kw electrical heaters which are strapped to the pipe legs on the bottom of the surge tank. The pressure is controlled by a Bailey pressure controller and a General Electric Reactrol.* The power to the heaters is measured by a recording wattmeter. The maximum power to the heaters is limited to 20 kw for safety purposes. The pressure in the surge tank and in the system is monitored by two pressure gages.

Other pressure gages monitor the pressure of the process water, demineralized water, flushing steam, and makeup water. There are six Barton Co. differential pressure gages on the panel board which measure the pressure drop across the pumps, pump filters, test-sample tube, control-sample tube, test specimens, and ion exchange filters.

Temperature control. The loop temperature is maintained by the line heater section of the loop system. The control of the electrical power to these heaters originates from a Brown potentiometer-type indicator controller which receives its input signal from an iron constantan thermocouple at the outlet of the line heater section. The temperature controller operates a General Electric Reactrol unit which controls the heater power. This system will maintain the loop temperature with very little variation. A recording wattmeter measures the power consumption of the heaters.

An additional 24-kw line heater section has been added to the loop to supplement the former heating capacity. This additional capacity is manually controlled and can be turned on in two steps of 12 kw each. After these heaters have been turned on, any fine variations in power requirements will be accommodated by the Reactrol unit.

Thermocouples are located at all points where it is considered necessary to monitor or record temperatures. Most of the thermocouples run to a common jackboard, thereby making it possible to plug any desired thermocouple into either a Brown six-point temperature recorder or a Brown 24-point precision indicator.

The thermocouples monitoring the temperature of the test-sample tube tip are run to a twenty-four-position selector switch which enables the operators to select any thermocouple and read its output on a potentiometer. One thermocouple, the one reading the highest temperature, is connected to a single point temperature recorder so as to have a continuous record of the test-sample tube tip temperature. The recorder has a switch that is set at 675° F so that, should the tube tip temperature rise to this value, a reactor scram will be initiated.

Flow control and measurement. The circulation of water must be maintained in the loop at all times to cool the test-sample tube tip. To maintain the required flow with some measure of safety, three pumps are provided. The pumps are connected in parallel with one operating and the other two on standby. The pumps are connected to the reactor failure-free power system to insure against loss of electrical power to the pumps.

The flow is controlled by a hand-operated 2-in. Annin Co. flow control valve. Since the flow is fairly stable it is not necessary to adjust the valve opening very often during a cycle.

The flow is measured with an orifice plate and a Foxboro air-operated flow recorder (DP cells). Two air-operated pressure switches are initiated by the same flow signal emitted by the DP cells. One switch produces an alarm and turns on the first standby pump at low flow conditions, and the other produces a reactor scram at a very low flow condition.

When the loop is circulating process water, the flow is measured by another orifice plate and Foxboro DP cell. The system of process-water flow measurement, signal transmission, recording, and alarm is the same as for the main water flow except for the pressure rating of the DP cell.

Miscellaneous flow, the cooling oil flow to the water pumps, and the ion exchanger flow rate are measured by rotometers. The rotometer for the cooling oil flow is equipped with an alarm to signal low flow conditions and to switch over to the standby pump.

Surge-tank level indication. The surge tank level is indicated and recorded on a Barton DP cell recorder. The signal to the recorder is transmitted by two tubing runs from the surge tank. The signal to the high side of the instrument comes from a standpipe which is the reference or cold leg. The reference leg is always at a constant level and is connected to the top of the surge tank. This leg is also cooled to maintain the water at a constant density. The signal to the low side of the instrument comes from the surge tank and varies with the level of the water in the tank. A slight correction must be made in the level readings to compensate for density differences between the reference and measuring legs due to temperature variation in the respective legs.

The liquid level recorder has both high and low level alarm set points. The high level alarm will automatically shut off the makeup pump in the event it is being used for filling the tank. The low level alarm point is set to automatically shut off the surge tank heaters to prevent their burning out or overheating during low level conditions.

Water activity monitoring. Loop activity is monitored by two small ion chambers that encircle the inlet and outlet piping of the test-sample tube. The signals from the ion chambers are amplified by two special amplifiers and then recorded by a circular chart recorder. The recorder is equipped with an alarm point so that in the event of an excessive increase in water activity, such as encountered during a fuel-element rupture, the operators would be notified and the loop would be shut down.

Saturation monitoring. Since it is necessary to maintain the water in a liquid state in the loop at all times, the loop water is continuously monitored by an instrument that automatically determines whether the water is approaching saturation conditions. This instrument receives pressure and temperature signals from the loop and automatically calculates the saturation pressure for this temperature and then scans the pressure differential between the loop and saturation pressures. If the pressure decreases or the temperature increases so as to approach saturation conditions, an alarm is sounded. If the condition persists for 2 sec, the heat exchanger is turned on to full capacity. If the saturation condition should continue for a period of 15 sec after the alarm without being rectified, the reactor is automatically scrammed. The instrument will measure saturation conditions for any pressure exceeding 200 psi.

* Registered Trade-mark General Electric Company.

Are Conventional Components Delaying Nuclear Progress?

NUCLEONICS *herewith presents excerpts from a challenging address delivered before a Navy group in Washington last month by Rear Admiral H. G. Rickover, chief of AEC's Naval Reactors Branch. The provocative and controversial address has aroused considerable interest.* NUCLEONICS *will welcome comments on this subject, pro or con, from readers.*

THE ONE FACTOR which today most severely limits our exploitation of nuclear power is neither legal nor governmental. It is not a lack of new ideas, nor a lack of understanding of recently developed ones. The main problem is with materials and equipment generally considered as conventional, but which must conform to the exacting standards required of all components of a nuclear power plant.

Successful operation of a nuclear power plant depends on the reliability of all its parts—not alone the reactor, but also the heat exchangers, pumps, valves, etc. Our experience with the four operating plants of the naval reactors program has shown that it is these components which have proved less reliable than the reactor itself. Also, the cost of these components has been high and delivery time poor.

It has been very difficult to get sufficient effort directed toward the more conventional aspects of nuclear plants —the heat exchangers, the pumps, the valves, the instrumentation. Normal engineering and manufacturing techniques have proved inadequate when applied to nuclear plants.

The necessity for improving design and performance of conventional-type equipment is apparently either not understood or disregarded. As a result, not enough effort is being expended to improve this equipment so that it can meet the exacting demands of nuclear power applications. The extent of this neglect cannot be measured in time and dollars alone; it must also be measured in terms of one of our scarcest and most priceless assets—trained technical manpower.

Three Main Factors

Three main factors are responsible for most of our difficulties in applying conventional-type components to nuclear power plants:

1. the need for shorter manufacturing time than is customary in conventional power plants;
2. the use of materials in shapes and under conditions different from those with which industry has experience;
3. the need for more rigorous criteria to evaluate the adequacy of materials and equipment.

There are good reasons for requiring shorter manufacturing times. The development of a nuclear reactor is a technically difficult and time-consuming undertaking. If the U. S. is to capitalize on any technological lead we may have in this field, our nuclear power plants must be built in a short time. For this reason our practice is to order the conventional-type equipment for nuclear plants as soon as a preliminary design of the nuclear reactor has been firmed up. But our invariable experience has been that industry cannot deliver this equipment as quickly as it is needed; this prevents us from fully exploiting our technological advantages. This is a sobering fact, especially since the welfare of our country in the future may well depend on the rapidity and the effectiveness with which we can exploit new concepts.

Second, nuclear power plants today require components which have different shapes and which are capable of operating under different conditions than those with which industry has had experience. We had expected that industry's technological know-how was sufficient to take care of these modest departures from conventional practice. We found this not to be so; in fact, we found that industry frequently has inadequate understanding of the fundamentals involved even in straightforward applications. For this reason many of our problems have had to be solved by empirical means. We have been forced to try many approaches, hoping that one would work. We cannot afford to continue trying several possibilities. We must first understand why something will or will not work. Until the fundamental processes involved are understood, each new, even slightly different, problem will have to be solved as it arises. This empirical approach is enormously wasteful of money and trained technical manpower; it also results in unexpected and unexplainable flaws and failures. These continue to plague us, and cause considerable delay.

Finally, the necessity for use of more rigorous inspection criteria arises from the emphasis we necessarily place on reliability. Failure of a component in a nuclear power plant has far greater significance to plant safety and operation than a similar failure in a conventional plant, because of radioactivity hazard and the resultant difficulty of access for maintenance and repair.

Thus it is clear that conventional-type components used in nuclear power plants must meet far more exacting standards than when used in normal industrial applications.

Technical Problems

There is lack of fundamental understanding even of common materials and of their fabrication.

Stainless steel. Our present knowledge of stainless steel is far from satisfactory. We have had to devote excessive attention to its fabrication and weldability to assure that the end product will be satisfactory.

Steam generators. Many of our steam generators use stainless steel tubes. Despite every design and operating precaution taken, we have experienced leaks in some of our steam generators. One corrective measure is to

. . . So says Admiral Rickover ➡
charging industry lacks understanding
of straightforward engineering

stress-relieve the stainless steel tubing to minimize corrosion. The manufacturers of this equipment have had years of experience in fabricating tubes. Yet, when they were confronted with the requirement to stress-relieve stainless steel tubes, without resultant surface contamination or distortion, they needed no less than five months to develop their processes, a delay not anticipated by us which caused a corresponding delay in completion of the steam generators for one of our ships. But even after this delay and expenditure of close to $1-million, we still lack a good understanding of this problem.

Forgings and castings. Obtaining sound carbon steel forgings and castings has continuously plagued us and is a major problem. Experiences with defective forgings and castings have forced us to order twice as many as are actually needed in order to insure a sufficient number of satisfactory ones. For example, one of our contractors needed 50 large forgings, yet 100 had to be made in order to supply these 50; the other 50 were so poor they had to be scrapped. During the next five years I estimate the naval reactors program alone will require about 600 large forgings. If the present rejection rate continues, 600 more forgings will have to be made and scrapped, at a waste of millions of dollars.

Stainless castings. The same is true of large stainless steel castings, many of which have had gross defects. We have had to become reconciled again to the fact that extra units must be made to be certain of obtaining a sufficient number of good ones. We still have not learned why these difficulties arise. I estimate that 2,750 castings weighing about 7.5-million lb will be required in the naval program during the next five years. If the present rejection rate continues, 4,100 castings will have to be made. Cost of the additional castings to be scrapped is estimated at several million dollars.

Management Problems

There is also lack of management attention to the work, both from an organizational and a detailed technical standpoint.

We have found that before a company can produce heat exchangers, valves, pumps, or instruments suitable for a nuclear power plant, a complete revision of its normal organizational procedures is necessary. A full-time project manager responsible directly to top management must be placed in charge of the nuclear products. He must establish new levels of engineering and scientific competence. This generally requires that personnel be given special education and training—academic evening courses at nearby schools or universities, and practical courses at the plant itself. Management will have to pay more attention to the training of personnel in administrative methods and in purchasing and expediting. New tools and procedures for inspection must be developed and put into use. Facilities for testing raw materials and the final product must be designed and installed. Often these are very expensive.

In short, an entirely new level of technical and administrative competence must be built up for even the so-called conventional-type equipment.

For example, in one experimental program nine small industrial-type pumps were ordered, one at a time, over a period of a year by our laboratories. These were a standard commercial product, ordered from several companies out of their catalogs of stocked items. They were to be used for laboratory tests of a completely non-nuclear nature. Yet each of the nine pumps had some serious defect upon delivery: poor castings which allowed gross leakage, misalignment which prevented operation, incorrect material used. Such defects can easily be corrected in most applications; in a nuclear power plant, however, where radioactivity is involved, such defects are intolerable.

Contrast this situation with the performance of the special canned-rotor pumps we had to develop for nuclear application. These developmental pumps, welded into place, require no lubrication and have run for years without inspection. They have received no attention and show no signs of needing any. Because of their reliability they are now also finding use in non-nuclear applications.

These difficulties represent a very small number of those we have so far encountered.

Lessons Learned

Two lessons stand out:

1. Too much dependence is currently being placed on routine design and production methods. Practical nuclear power cannot be achieved by routine methods. The performance and safety standards of nuclear plants pose problems requiring technology far in advance of that now being used. We have found from repeated experiences that the only way these problems can be solved is by special, persistent attention by management.
2. Companies should determine where their background and talent can best meet the needs of nuclear power. For most companies this is not in the design of the reactor itself; rather it lies in the development or perfection of reliable, higher performance materials and components. Right now nuclear power requires that practically everything be designed by scientific methods.

Today there exists both a great opportunity and a great challenge in the nuclear power field. Those who realize that a major function of management is to plan for the future, and who are willing to undertake difficult work, including achievement of better understanding of fundamentals, will be the ones who remain in this field.

Gamma-Ray Dose and Heating from Spent MTR Fuel Elements

Spent MTR elements are now available as gamma and heat sources. Given irradiation history of element, gamma dose rate can be calculated. Verification of heat calculations awaits more accurate calorimetry

By W. E. FRANCIS and L. L. MARSDEN
Phillips Petroleum Company, Atomic Energy Division, Idaho Falls, Idaho

WITH SPENT MTR FUEL assemblies being used as sources of high-intensity gamma radiation, not only at the National Reactor Testing Station, but also at various other installations in the United States (*1*), a comprehensive study of the energy available from these elements during their "cooling period" became essential.

The results are presented here of a project at the Materials Testing Reactor to measure and calculate gamma intensities and heating values from spent fuel elements as a function of fission time, cooling time, and distance from source. Fuel elements with cooling times from 3¾ hr to 218 days after reactor shutdown and fuel burnups of 3.5–35% were studied.

Fuel as γ-Ray Source

The following discussion compares measured and calculated gamma dose rates from spent fuel elements. Both the calculated and measured data pertain to the same five elements. Two were one-cycle elements, two were two-cycle, and one was a three-cycle.*

Measured dose rate. To measure gamma intensities, single elements were placed flat on a bench under approximately 14 ft of water. A metallic strip calibrated in inches was placed beside the element. An air-gap ion chamber with positioning lugs was used to measure the gamma intensities at distances of 1 in. to 1 ft from the face of the fuel element. Readings were taken from all four sides of the element throughout the fuel-bearing section.

Figure 1 contains the results of surveying five elements throughout their cooling cycles. These elements were chosen particularly because of their differences in fuel burnup and in reactor histories. These parameters appear in the curves as differences in absolute values, the slopes being similar.

Predictions of dose rates can be obtained by correlating a particular situation to the nearest curve of Fig. 1. It is noted that increased fuel burnup normally results in higher dose-rate readings; two-cycle burnup gives higher values than one cycle. The effect of reactor history is apparent, however, since the two-cycle 58-gm-burnup

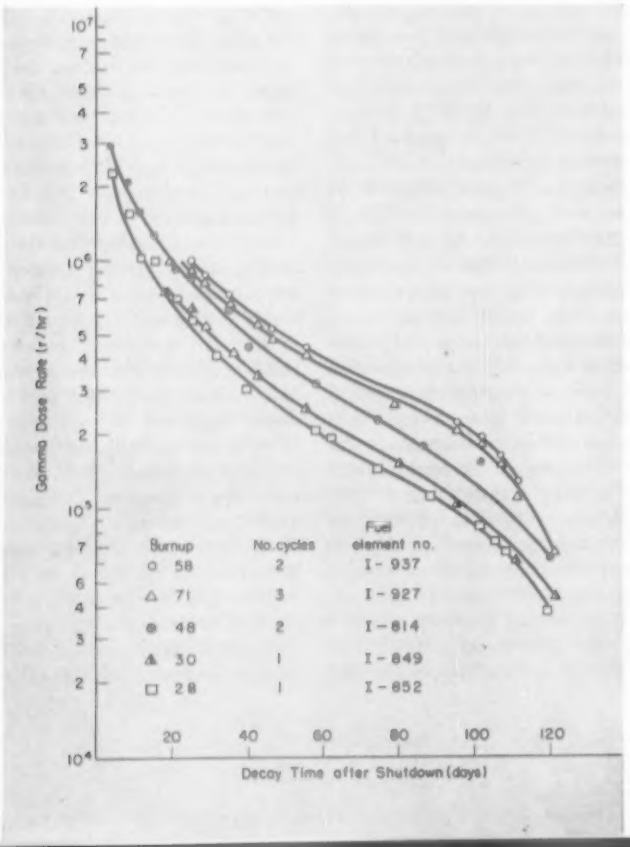


FIG. 1. Cooling cycles of five spent MTR fuel elements. Dose rate was measured by ion chamber 3 in. from element side plate at midplane

*An MTR cycle is one period of reactor operation, usually 15–17 days, after which the reactor is refueled and experiments modified for the next cycle.

curve is higher than the three-cycle 71-gm-burnup curve.

A series of gamma traverses are shown in Fig. 2. The element was chosen as typical of a short cooling period. Figure 2 illustrates the truncated curve obtained on fresh elements when readings are taken close to the surface of the element. Limitations in the ion chamber are believed responsible for this phenomenon.

Figure 2 indicates that very little difference exists between sides. The biggest difference (and even its significance is questionable) appears to be between sides 2 and 4, presumably caused by their convexity and concavity.

Because of its simplicity and rapid indication for the vast number of readings required, the ion chamber was used for all fuel-element scanning. A rod-type calorimeter, a ceric dosimeter, and silver-activated phosphate glass were used for chamber calibration.

Calculated dose rate. Intensities were calculated for cooling times of 1–200 days at close enough intervals to enable adequate curves to be drawn for each of the spent elements. The reactor time in each case was 15–17 days. The dose rate is computed by summing the dose rates in r/hr from each of the seven energy groups given in the table.

A fuel element was considered to be a cylindrical source. The intensity was calculated, in all cases, opposite the center of the element (see Fig. 3).

Calculations were based on the equation for the undirected energy flux (*2*)

$$\phi_E = B\frac{Q_v E C^3}{2(a+Z)}e^{-b}\int \sec\theta\, d\theta \quad (1)$$

where ϕ_E = undirected energy flux (Mev/cm²/sec); E = energy of primary γ-rays (Mev); B = buildup factor to correct for multiple scattering; Q_v = source strength of a volume source (γ-rays/cm³/sec); C = radius of cylindrical source (cm); a = distance from source to observer (cm); Z = effective self-absorption distance (cm); and $b = \mu_w a + \mu_s Z$, where μ_w and μ_s are absorption coefficients (cm⁻¹) for water and source, respectively. Note that ρ, the average density of the assembly plus water, was calculated to be 1.65 gm/cm³. Since this was close to the density of carbon ($\rho = 1.67$), the carbon absorption coefficient was used. By substituting $b/1.2$ for b, B is implicit in Eq. 1 (*3*).

The dose rate at point P (Fig. 3) (*4*) is

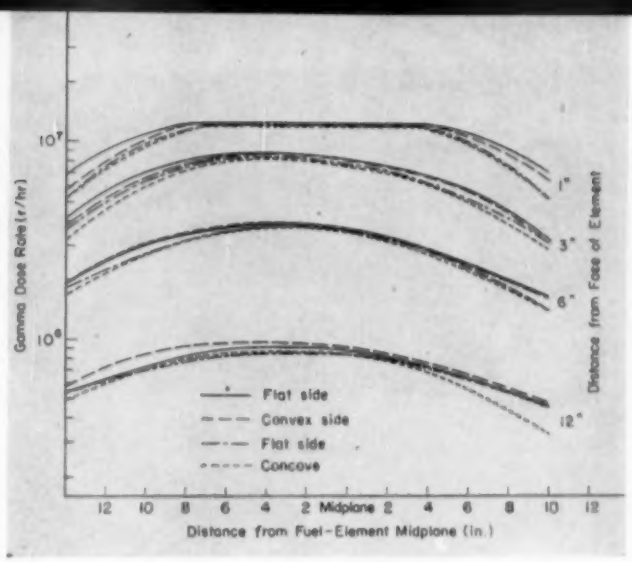


FIG. 2. Ion-chamber survey of fuel element I-987, 4 hr after shutdown and at various distances from face of element

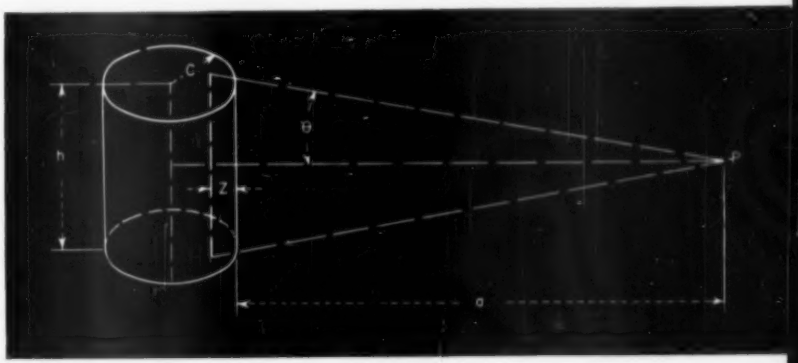


FIG. 3. Parameters for calculating dose rate from cylindrical fuel element

$$I_\gamma = \frac{\phi_E\left(\frac{\mu-\sigma_s}{\rho}\right)\times 3{,}600}{51.8\times 10^6}$$

where I_γ = dose rate (r/hr); σ_s = scattering cross section of water; 3,600 = sec/hr; 51.8×10^6 Mev absorption/gram of air = 1 r; and $(\mu - \sigma_s)/\rho$ = ratio of macroscopic cross section for energy absorption to density of tissue (cm²/gm) (ref. *5*, supplement 4).

Since the calculations were based on 1 fission/sec, the average fissions/sec/cm³ is

$$\frac{\Delta M N_0}{ATV} = 8.47\times 10^{13}\Delta M/t$$

where ΔM = burnout per fuel element (gm); N_0 = Avogadro's number; T = time (days); V = volume/fuel assembly = 3.5×10^3 cm³; t = irradiation time (sec); and A = U^{235} atomic mass.

The procedure for calculating the total dose rate from a multicycle element is as follows:

1. Calculate the dose rate after each cycle.
2. Add the individual rates, allowing the correct number of days' cooling after each cycle, to obtain the total gamma-decay dose rate.

Figure 4 illustrates this method.

Figure 5 compares the theoretical calculations and the experimental measurements for a typical fuel element. The agreement is good for thin shields but becomes increasingly worse as the shield thickness increases.

Fuel-Element Heat

Direct comparisons of the dose-rate curves with the heating curves cannot be made since the former account for gamma intensity only, while the latter include the beta heat as well as gamma heat. Following is a comparison of

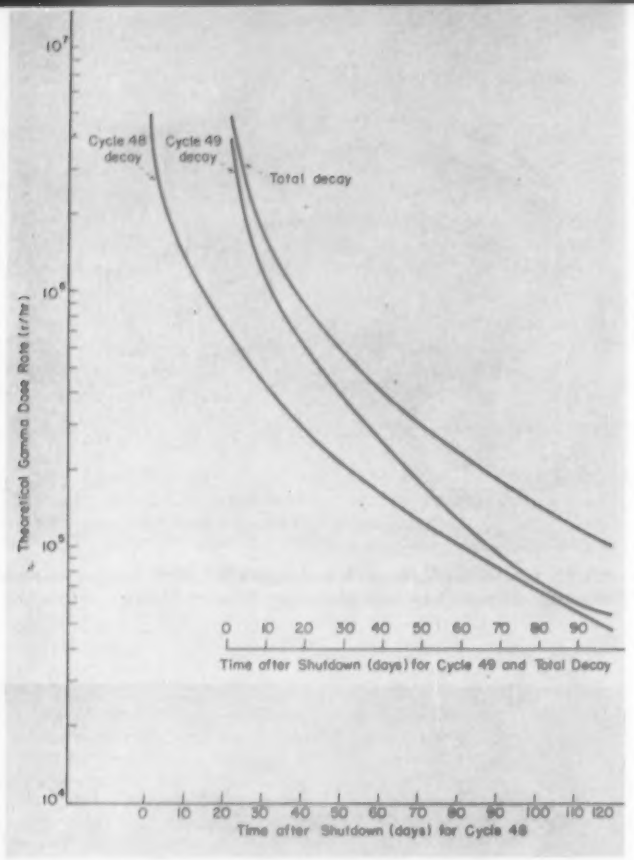

Cycle 48 decay
Cycle 49 decay
Total decay
Theoretical Gamma Dose Rate (r/hr)
Time after Shutdown (days) for Cycle 49 and Total Decay
Time after Shutdown (days) for Cycle 48

FIG. 4. Procedure for calculating total gamma dose rate for multicycle elements (data given here for element I-937; measured through 3 in. water). Total decay is sum of decays resulting from cycles 48 and 49

measured and calculated heat from spent fuel elements.

Measured heat. The equipment used for measuring heat from a spent fuel element is sketched in Fig. 6.

The calorimeter consisted of a double-walled tank designed to hold one fuel element. Insulation between the walls was provided by a 1¼-in. air gap. Four Calrod-type heating elements spaced at 90 deg were installed in a vertical position inside the vessel. These provide a wide range of electrical heating (up to 2,800 watts) for calibration purposes. Four thermocouples, two at centerline and one each at top and bottom, were connected through a switch to a portable potentiometer. Electrical input power was measured by a wattmeter, while water flow rates for dynamic tests were indicated on a rotameter. Valves permitted isolating the tank for batch trials.

A dummy fuel element was placed in the tank and a series of runs made in which the electrical heating was varied. The majority of the work was done by batch heating since low heating rates produced temperature differentials too small to be measured well.

Several series of runs were made in which spent fuel elements having different cooling times were inserted in the test rig, the electrical heating varied from zero to maximum, and the heating rates determined.

The test runs in which the electrical heat was zero gave heating rates due solely to the fuel elements. These rates were then deducted from the runs with combined heating. The result was a series of data of heating rates vs. electrical heating. These data, combined with those from the dummy runs, gave a calibration curve that could then be used for converting heating rates, determined from any spent fuel element, to equivalent heating. This procedure corrected for heat losses from the calorimeter without necessitating a separate calculation for each run. A series of spent fuel elements ranging in cooled age from 18½ hr to 121 days were measured; see Fig. 7.

Calculated heat. The theoretical heating in terms of watts was obtained for given cooling times. Again calculations were made on several different elements, including the same elements as those in the dose-rate calculations.

The expression for the gamma heating (H_γ) is

$$H_\gamma = 1.6 \times 10^{-13} Q_v E_{avg} FV$$

where Q_v = γ-rays/cm³/sec; 1 Mev/sec = 1.6×10^{-13} watts; E_{avg} = average energy for given group (Mev), considering same seven energy groups as in gamma-intensity work; F = number of fissions per second; V = volume of fuel element (3.5×10^3 cm³).

The heating from the beta activity is assumed to be 1.11 times the total gamma heating (*6*). This approximation is assumed to be good within a factor of two for periods of time $10 < t < 10^7$ sec (~116 days).

Since the calorimeter and surrounding water do not absorb all the gamma radiation, the gammas escaping from the calorimeter were assumed equal to $e^{-\mu r}$, where μ is the mass-absorption coefficient of water (cm⁻¹) (*5*) and r is the thickness (cm) of the water layer in the calorimeter plus the stainless-steel

Energy Groups of Fission-Product Gamma Decay*

Cooling time (days)	*Gamma-ray energy, E (Mev)*						
	2.5	*1.75*	*1.25*	*0.9*	*0.7*	*0.5*	*0.35*
1	0.002810	0.043500	0.023100	0.009500	0.152000	0.047500	0.056000
5	0.001520	0.032000	0.005620	0.007000	0.026400	0.017800	0.037900
10	0.000850	0.021900	0.001980	0.005600	0.014300	0.012800	0.026500
50	0.000121	0.002010	0.000001	0.001360	0.006200	0.003070	0.003400
100	0.000045	0.000118		0.000382	0.003550	0.000980	0.000468
150	0.000029	0.000005		0.000154	0.001880	0.000458	0.000100
200	0.000024			0.000076	0.001040	0.000250	0.000027

* Decay rate, Q (photons/sec), for 17-day irradiation and normalized to 1 fission/sec. Total photons/sec within each energy group and absorption coefficients for all gammas in group were based on these average energies.

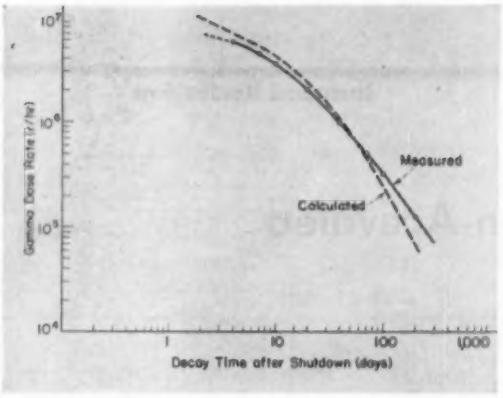


FIG. 5. Measured and calculated gamma dose rate for fuel element I-814 through 1.25 in. water

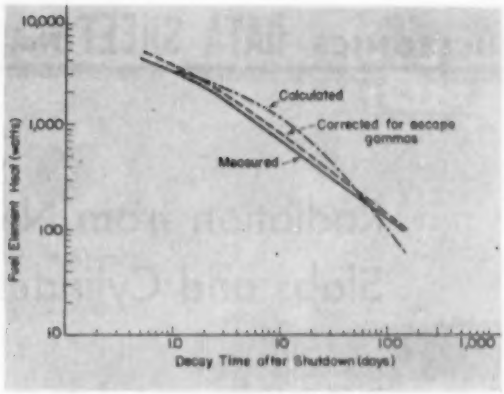


FIG. 7. Calculated and measured heat from spent MTR fuel elements

thickness expressed as the equivalent distance in water.

Conclusions

The following points summarize some of the more important aspects of the project:

1. Experimental measurements and theoretical calculations of dose rates for spent fuel elements are in good agreement for small distances from the element (<3 in. in water). As the distance from the element increases the agreement is not as good.

2. The dose rate of any spent fuel element, regardless of number of cycles in the reactor or length of time between cycles, may be calculated by summing the individual decay rates adjusted for the proper cooling time. This procedure is illustrated in Fig. 4.

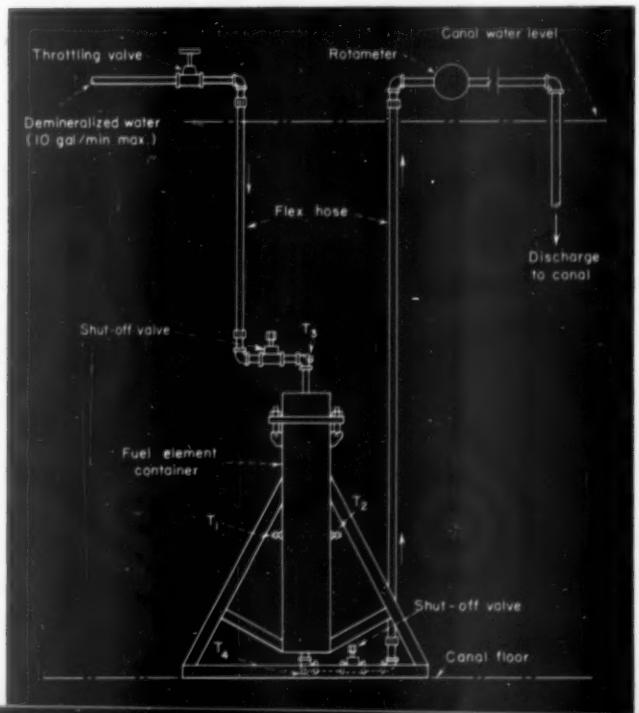
3. Since the inception of this project, MTR power was increased from 30 to 40 Mw. Although the data reported here were taken on spent fuel elements from 30-Mw operation, it is of interest to determine the dose rates to be expected from 40-Mw operation.

It was anticipated that the dose rate would increase proportionally with the power, assuming the same reactor time and position. The dose rates measured after 40-Mw operation were not appreciably different from those taken at 30 Mw for equivalent cooling times. This may be explained, at least partly, by the fact that the 40-Mw elements received more intermittent burnup; the cooling intervals thereby assume more importance in the final dose rate, tending to lower this value. Flux mapping in the reactor has also indicated a lower peak-to-average value for the 40-Mw operation than at 30 Mw, which would also account for a lower dose rate than expected.

4. The air-gap ion chamber has proved to be a reliable instrument in the range 10^5–10^7 r/hr and may reasonably be extended to 10^4 r/hr.

5. Averaged values of measured heat from spent fuel elements are somewhat lower than the calculated values except for long cooling times. Unlike those of gamma intensities, the slopes of the measured and the calculated heats in Fig. 7 are not similar. This is attributed to the wide fluctuations in individual heat measurements when applied to a calibration curve. Particularly for low heating values where batch procedures were used for measurement, large errors are possible. Modifications of the test calorimeter would be required for more precise measurements.

FIG. 6. Fuel-element calorimeter ($T_{1,2,3,4}$ are thermocouples)



* * *

This article is based on a paper presented before the American Nuclear Society meeting, Chicago, June 6–8, 1956.

BIBLIOGRAPHY

1. Nucleonics **14**, No. 10, R-12 (1956)
2. T. Rockwell, A. S. Kitzes, ORNL-710, p. 292 (1950)
3. G. Ascoli, O. Sisman, ORNL-53 (1948)
4. L. H. Boyer, IDO-16066 (1953)
5. J. L. Powell, W. S. Snyder, ORNL-421 (1950)
6. Clark Goodman *et al.*, "The Science and Engineering of Nuclear Power" (Addison-Wesley Press, Cambridge, Mass., 1947)

Radiation from Neutron-Activated Slabs and Cylinders

By W. B. LEWIS
Atomic Energy Division
Phillips Petroleum Co.
Idaho Falls, Idaho

THE RADIATION from an object activated by irradiation in a neutron flux that is uniform and isotropic depends on the manner in which the induced activity is distributed through the sample volume and on the absorption coefficient of the object for the radiation under consideration. The distribution of induced activity depends on the shape of the sample and on the coefficient of absorption for neutrons.

The effective activity, defined as the ratio of the amount of radiation leaving the surface to the total amount induced in the object, can be determined by solving two problems sequentially. First, the distribution of the radioactive nuclides must be determined. Second, the fraction of radiation reaching the surface from an element of volume must be calculated, and an integration made over the entire volume.

These problems have been solved for two simple cases: (1) a sphere of radius a and (2) an infinite slab of half-thickness a. Three quantities are displayed: the density distribution Z, the effective activity s, and contours of constant s. Figure 1 shows these for spheres, and Fig. 2 for slabs.

Analytical expressions can be obtained for four quantities. These are tabulated below. The general functions $s(B_n,B_\gamma)$ are obtained by interpolation.

The contours of $s(B_n,B_\gamma)$ offer a quick means to evaluate the effective activity. It is necessary only to evaluate B_n and B_γ from the physical constants of the sample and locate the corresponding point on the map. The accuracy of the value obtained is about $\pm 10\%$. The contours cannot be used when both B's are close to unity. In such cases recourse to numerical integration is necessary, or, better yet, just irradiate and see what happens.

Example: Suppose we irradiate a typical iridium sphere having the following characteristics: mass = 800 mg, $\mu_n = 30.8\,\text{cm}^{-1}$, $\mu_\gamma = 8.0\,\text{cm}^{-1}$, $a = 0.204$ cm, $b_n = 6.08$, $b_\gamma = 1.63$, $B_n = 0.9977$, $B_\gamma = 0.805$.

Since b_n is large, most of the activity is produced in a thin outer shell, and since b_γ is fairly large, the efficiency of recovery should be about 50%. The problem is complicated by the large range of gamma energies. There are 11 gammas listed for Ir with energies ranging from 0.136 to 0.613 Mev. The value chosen for μ_γ is a good estimate for four gammas that account for 80% of the total energy: 0.296, 0.308, 0.316, 0.468 Mev.

Values of s are 0.50 from Fig. 1 and 0.59 from numerical integration.

Quantities Important in Evaluating Neutron-Induced Radiation

Quantity	*Value for sphere*	*Value for slab*
$Z(b_n,x)$	$\frac{e^{-b_n}}{2}\left[\cosh b_n x + (1+b_n)\frac{\sinh b_n x}{b_n x}\right] - \frac{b_n(1-x^2)}{4x}E$	$e^{-b_n}\cosh b_n x + \frac{1}{2}\{b_n(1+x)\,\text{Ei}\,[-b_n(1+x)] + b_n(1-x)\,\text{Ei}\,[-b_n(1-x)]\}$
$Z_{ave}(b_n)$	$\frac{3}{8b_n^3}[2b_n^2 - 1 + (2b_n+1)e^{-2b_n}]$	$\frac{e^{-2b_n}}{2} + \frac{1}{4b_n}(1-e^{-2b_n}) + b_n\,\text{Ei}\,(-2b_n)$
$s(0,B_\gamma)$	$\frac{3}{8b_\gamma^3}[2b_\gamma^2 - 1 + (2b_\gamma+1)e^{-2b_\gamma}]$	$\frac{e^{-2b_\gamma}}{2} + \frac{1}{4b_\gamma}(1-e^{-2b_\gamma}) + b_\gamma\,\text{Ei}\,(-2b_\gamma)$
$s(1,B_\gamma)$	$\frac{1}{2} + \frac{1}{4b_\gamma}(1-e^{-b_\gamma})$	$\frac{1}{2}(1+e^{-2b_\gamma}) + b_\gamma\,\text{Ei}\,(-2b_\gamma)$
$s(B_n,0)$	1	1
$s(B_n,1)$	0	0

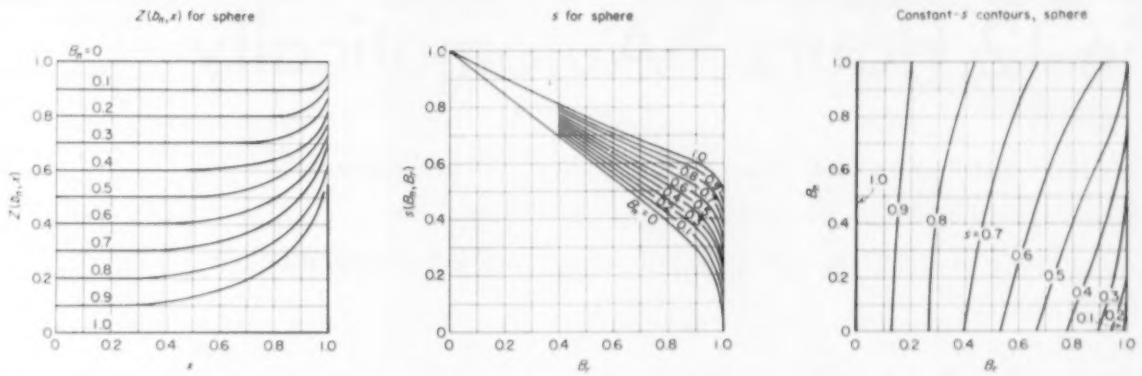


FIG. 1. Quantities needed for evaluation of radiation from neutron-activated sphere. $Z(b_n,x)$ is plotted as a function of x for different values of the parameter B_n (see table of symbols). Values of $s(B_n,B_r)$ are plotted as functions of B_r, B_n being the parameter. Contours of constant s are shown on a map of B_n and B_r

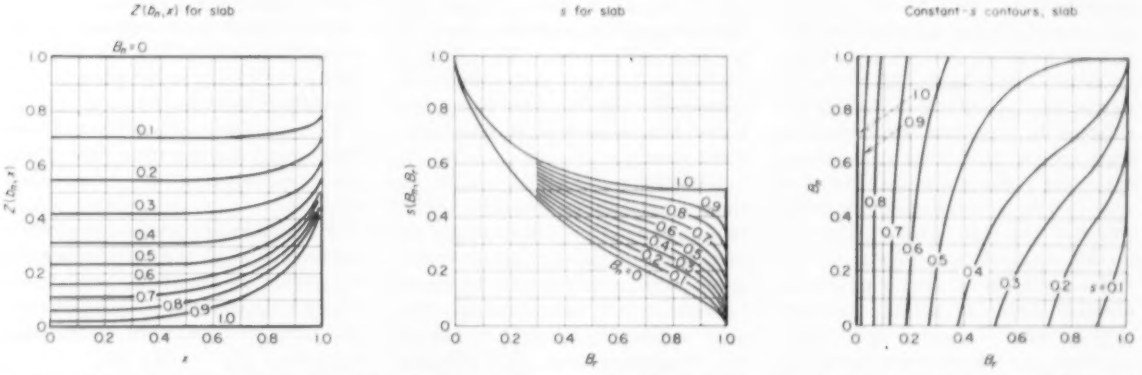


FIG. 2. Quantities $Z(b_n,x)$ and s and contours of constant s that are used to determine radiation from irradiated slabs are displayed in same manner as those for sphere that are displayed above in Fig. 1

Symbols

a = *significant length (radius of sphere, half-thickness of slab)*

xa = *distance from center of sphere or midplane of slab to volume element*

ha = *distance from volume element to surface element*

μ = *absorption coefficient*

n = *subscript referring to neutrons*

r = *subscript referring to induced radiation*

$b = \mu a$

$B = 1 - e^{-b}$

$E = \int_{b(1-x)}^{b(1+x)} e^{-y}\,dy/y \equiv \mathrm{Ei}[-b(1+x)] - \mathrm{Ei}[-b(1-x)]$

ϕ = *neutron flux* $(n/cm^2/sec)$

ϕt = *integrated neutron flux* (n/cm^2)

$Z(b_n,x)$ = *distribution function for induced activity*

$$= \int_S e^{-b_n h}\rho(B_n,x)\cos\theta\,dV/4\pi h^3 a^2$$

ρ = *actual volume density of radioactivity* $(dps/cm^3) = \mu_n\phi t Z$

$\sigma(B_n,B_r)$ = *surface density of radioactivity of equivalent thin shell* $(dps/cm^2) = \int_V e^{-b_r h}\rho(B_n,x)\cos\theta\,dV/4\pi h^3 a^2$

$s(B_n,B_r)$ = *ratio of equivalent-surface activity to total induced activity*

$$= \int_S \sigma\,dS \Big/ \int_V \rho\,dV = \sigma_{avg}S/\rho_{avg}V$$

$\sigma_{avg} = \int_S \sigma\,dS/S$

$\rho_{avg} = \int_V \rho\,dV/V$

$Z_{avg} = \rho_{avg}/\mu_n\phi t$

Counting Thousands of Samples in 12 Hours—Automatically

Neutron-distribution plots can be produced quickly and accurately by using foil and wire neutron activation combined with automation of counting, data processing and machine computation

By KENNETH E. RELF
Bettis Plant, Westinghouse Electric Corp., Pittsburgh, Pennsylvania

THE VALUES of many important reactor-core design parameters are determined by counting foils or wires activated at strategic points within the core. To secure sufficient data, one or two thousand points per day must be obtained, and the corrected data, to be of maximum use, should be available within a day or two. Counting many identical samples is repetitive and therefore lends itself to automation. Processing the count rates is also repetitive, involving simple subtraction and multiplication, and therefore is adaptable to machine-computation methods.

Several types of counting systems utilizing some automatic apparatus such as sample changers, wire or tape scanners, and timing devices have been described in the literature (*1–3*). While automatic timing devices and sample changers relieve an operator of the tedium of counting measurements, automation goes beyond this. Automation more fully releases skilled help and can contribute vital information that otherwise would not be obtained or made available. The system to be described makes use of automation and digital computers to produce finished flux plots ready for interpretation.

Advantages

The time required to process the data from 2,000 foils on manually operated calculators compared with the time required by automatic data processing indicates the significant improvement in efficiency that can be achieved with modern automation. Two years' experience with manually operated calculators demonstrated that an efficient operator could correct one data point per minute for background, decay, and interchannel normalization. Two thousand minutes (33 hr) would be required to obtain the corrected data from a single experiment—four 8-hr working days for one person. Because of fatigue, frequent rest periods were necessary. Usually, two persons required four or five 8-hr days to process 2,000 points.

With the new method, count rates from 2,000 foils are punched on 333 cards, and the IBM 650 computer corrects each of these points for background, decay, and channel-to-channel normalization at the rate of 50 cards/min. This represents approximately 7 min computing time. The 650 computer provides a set of output cards punched with the corrected count rates. These cards are the input data for the IBM 407 tabulator. The tabulator provides an output sheet with the corrected information in approximately 3–5 min. A total of 10 or 15 min is all that is required to furnish the designer with the corrected data from a set of 2,000 irradiated foils. To the computing time of 15 min must be added an hour or an hour and a half for preparing these cards for the computer. (Most of this preparation is done during the course of the run.) Preparation consists in correcting cards that may have been punched incorrectly by the IBM 519 punch and running the cards through the double-punch blank-column detection device and the IBM sorter. In any case, within 2 hr at most, a designer can have in his hands the results of the irradiation of 2,000 foils, whereas 4 or 5 days is required if the counting and processing were done manually.

Four distinct advantages are offered by the installation to be described:

1. It allows more efficient use of scientific personnel because they can interpret the data rather than concern themselves with the processing.
2. Experiments can be planned more intelligently because the results of previous experiments are immediately available.
3. An increase in over-all accuracy is achieved through the use of automatic sample changers, which position the samples beneath the scintillation crystal with a consistently reproducible accuracy.
4. Calculators can be better utilized because they can be assigned to problems unworthy of computer coding, or they can be assigned to problems not adaptable to machine computation.

Functional Description

The basic functions to be performed are detection, amplification, pulse shaping, discrimination, pulse registration, and program control. These are indicated in the table on p. 88

The irradiated samples are placed in specially designed, molded nylon sample holders. These holders have milled slots and circular wells. The slots accommodate wires either ½ or 1 in. in length, and the wells accommodate foils ¼ or ⅜ in. in diameter. The holders were molded in ten different colors to distinguish samples irradiated in different parts of the reactor or to distinguish types of irradiated foils.

Each sample changer will accommodate 73 holders. In order that the data obtained can be subjected to a code suitable for the IBM 650, the stack of 73 holders must contain not only the irradiated samples but also long-lived standard foils and empty holders arranged in a specified sequence.

When each of the six changers has been properly loaded, the counting program is initiated from the control position by the operator, who simply throws the count switch. The changers locate the samples to be counted beneath the scintillation crystals in approximately 20 sec. The change time for the particular changers in use is a nominal 15 sec, but 20 sec are allowed to be certain that all changers have placed the samples under the heads and all will be ready to count when the command is given.

Detection is accomplished with an anthracene scintillation crystal 1¾ in. in diameter and 1 mm in thickness. The low gamma-ray detection efficiency of anthracene reduces the background counting rate caused by other activated samples in the changers. The most usual counting rates range from a few thousand to 350,000 counts in 40 sec. On rare occasions they range from a few hundred up to one million counts in 40 sec.

The preamplifier differentiating time constant consists of input stray capacity in parallel with the input resistor selected to give an appropriate time constant, usually about five times the phosphor decay time. For an anthracene crystal, the decay time is about 2.7×10^{-8} sec (*4*). The signal from the preamplifier is transmitted to a main amplifier having a maximum gain of 3,000. Triaxial cable is necessary to minimize the spurious counts thrown into the circuit by the operation of the printers, the IBM punch, and the sample changers.

Further amplification, pulse shaping, and discrimination are performed on the same chassis. The main amplifier contains a second (0.3–200 μsec) time constant and a 1-μsec delay line for pulse shaping. The time constant in the preamplifier and in the main amplifier have been adjusted for the work in this laboratory so that the over-all pulse length is 6.2 μsec. (The positive pulse is 1.2 μsec in duration, and the negative undershoot is 5 μsec.) On the basis of probability theory, this pulse length allows a count rate of 100,000 cpm with the assurance that, on the average, not more than 1 out of 100 pulses will begin during the previous pulse. Preliminary checks on the resolving times of these channels indicate that there is no detectable loss in up to 250,000 cpm.

ELECTRONIC COMPONENTS of six-fold counting system

The amplifier output pulses are fed to the discriminator. The discriminator is basically a high-speed Schmitt trigger circuit whose output is a 45-volt negative pulse 0.6 μsec in duration. The pulse from the discriminator is fed to a pulse-registration unit commonly called a scaler but hereinafter called a recorder. The recorder has a paired-pulse resolving time of 0.85 μsec and consists of six decades capable of indicating six digits in lights (there is no mechanical register). The recorder operates a printer and a converter.

The printer is a Victor adding machine, which prints the nuclear count rate on cash-register tape. The converter transmits the digital information from the recorder to an IBM model 519 punch, which, in turn, punches these numbers in a standard IBM card.

The IBM card contains the following information from left to right:

Column number	*Information*
1–3	Run number
4–6	Serial number (of card)
7–11	Time (in seconds from reactor shutdown)
12–18	Channel 1 count
19–25	Channel 2 count
26–32	Channel 3 count
33–39	Channel 4 count
40–46	Channel 5 count
47–53	Channel 6 count

A distinct advantage in having both the printer and the converter is that the operator can make notes on the printer tape about sample designation, possible errors, or other information to aid in interpreting the final results.

Program control is accomplished with a Berkeley dual preset counter, which registers pulses from a 100-kc temperature-controlled crystal oscillator. The preset counter indicates an *A* time and a *B* time, both of which are adjustable from the front of the unit. The count is made during the *A* time. During the *B* time, the commands to print, punch, reset, and change samples are given. The difference between *A* and *B* is the time allowed for the sample changers to operate.

Data Processing*

The sequence in which the count rates of the irradiated samples, standard foils, and background are recorded must follow a predetermined pattern so that instructions for the computing machine can be formulated. A guaranteed sequence must be used because no system has yet been devised that will distinguish one type of count from any other by putting an identifying punch in the IBM card.

The stack of 73 samples, therefore, begins with two blank holders that permit background counts to be taken, followed by a holder containing a long-lived standard. The holders are succeeded by a set of normalization wires. This set can contain any number so long

* Mr. O. F. Swift of the Analysis and Computation Section kindly furnished the information presented in this section.

Components of Automatic Counting System

Component	*Brief description*	*Supplier*	*Approx. cost ($)*
Detection			
Anthracene scintillator and photomultiplier	1¾ in. diam × 1 mm Decay time: 2.7 ± 0.5 × 10^{-8} sec RCA 6342, 6655 or DuMont 6292	NRD Instrument Co., St. Louis, Mo.	270
Power supply	Range: 100–1,400 v in 17 steps Max. current: 1 ma Output: plus or minus Stability: 0.02% per day	Atomic Instrument Co., Cambridge, Mass. Model 312	455
Line-voltage regulator	Load range: 0–1,000 va Regulation accuracy: ±0.01% Harmonic distortion: 3% max Time constant: 0.1 sec	Sorensen & Co., Inc., Stamford, Conn. Model 1001	250
Sample changer	Capacity: 73 samples Change time: 16 sec	Nuclear-Chicago, Chicago, Ill. Model C-110A. Special lead shields ½ in. thicker than supplied were obtained to halve background	1,300
Sample holder	Molded nylon plastic	Parker Plastic, Pittsburgh, Pa.	
Amplification			
Preamplifier	Gain: 30	Cosmic Radiation Laboratories, Inc., Patchogue, N. Y.	85
Main amplifier	Gain: 3,000 Rise time: 0.15 μsec Clip time: 0.3–200 μsec Input: plus or minus Output: 100 v positive Stability: better than 1% for 72 hr Linearity: better than 1%, 0–100 v	"	400
Pulse shaping			
RC network and delay line	*RC*: 0.3–200 μsec Delay line: 1 μsec		—
Discrimination			
Schmitt trigger circuit	Output: 45 v neg Duration: 0.6 μsec		—
Pulse registration			
Digital recorder and printer	Recording and indicating capacity: 6 decades Max cycling rate: one print-out every 0.8 sec Input sensitivity: 0.6 v neg. with a rise time of 100 μsec Paired-pulse resolving time: 0.85 μsec	Berkeley Division, Beckman Instruments, Inc., Richmond, Calif.	1,570
Punch converter	The converter sets up a pattern of relay closures at the end of a count period corresponding to the digit lights on the recorder.	Berkeley model 1440-1	850
Summary punch	Machine will punch, reproduce, verify, and perform a blank-column double-punch search.	IBM type 519	220/mo
Program control			
Dual preset counter	Counting capacity: 1–1,000,000 Frequency of count: d-c–40,000 cps	Berkeley model 5446	860
Time base and reset chassis	Time base frequency: 1 kc or 10 kc Stability: 1 part in 10^4	Berkeley model 5632	740
			Total 6,780

as the same number of wires is inserted in the stack for each channel. The normalizing wires are followed by two blank holders, a long-lived standard, and two more blank holders. The irradiated samples are then stacked on top of this in groups of any number between 3 and 100.

In addition to a guaranteed sequence, the computer must be furnished with sample counts of no less than four digits and background counts not exceeding three digits. The computer distinguishes between a sample count and a background count by the magnitude of the number. The computer distinguishes standard counts from background and sample counts by noting that every standard count is preceded and followed by two background counts. From the point of view of the computer, there is a fourth class of counts called cancelled counts, identified by an 11-punch in the last column of the field allotted to a given channel. This punch instructs the computer to ignore the information in that field.

To minimize the constraints applying to any one channel, each counting channel can follow its own sequence; that is, the six channels need not be synchronized. On a given card, therefore, the types of counts punched need not be the same for each channel. Thus, the computer is required to do individual bookkeeping for each channel, which adds to the complexity of the coding. The storage limitation of the computer does not permit all the input data to be read into it at one time. The computer must decide when sufficient data are available to punch out the cards, and then it must provide room for more input cards. Though this further complicates the coding procedure, it has the advantage of permitting the number of input cards to be almost unrestricted.

The background correction for the irradiated sample counts is an average of each two consecutive pairs of background counts. This correction requires the machine to record and store the first pair of background counts it encounters. It must also store the next group of counts until it encounters the second pair of background counts. The four background counts are averaged, and this average is subtracted from each group of counts. This correction is recomputed each time the machine encounters a pair of background counts.

The irradiated samples are corrected for decay by the factor $e^{\lambda t}$, where t is the time from reactor shutdown and λ is the decay constant characteristic of the material. The machine computes this correction from the time, in seconds, punched in the card.

Interchannel normalization is accomplished by counting the same group of samples on each channel. The sensitivity of each channel is assumed to be proportional to the sum of the corrected counts, and the correction is made to the channel with the highest sensitivity. The machine records the sum of these corrected normalized counts and automatically multiplies all irradiated sample counts by the appropriate factor.

The IBM 650 computer reads input data at the rate of 200 cards/min, and during this time ¼ sec is available for machine calculation between cards. In this ¼ sec the computer checks the serial number of the card, records the punch time, identifies the type of sample count from each channel, places it in storage, and remembers background counts, cancelled counts, and uncorrected normal counts for each channel. It also determines whether enough data have been processed to produce output cards and, if data are sufficient, how many cards. Finally, the computer makes the background correction. A stop command is given to the computer if it encounters an incorrect serial number or if the backgrounds do not appear in pairs.

During the input operation, 0.6 sec is available for computation. In this time the code computes the decay factor, makes the decay and normalization correction, and keeps track of cancelled counts, background counts, completed groups of counts, and the serial number of the card being punched. It checks each item off the list compiled during reading so that the list for each channel remains up to date. When the punching is finished, the counts in storage are repositioned to a standard starting point, and instructions are modified to correspond to this new move. The card-reading cycle then resumes. The computation for this code is completed in a time not much greater than that required to read and punch the data cards.

The curve of total flux (bare-wire counts) shows too much detail to allow a smooth curve to be drawn through all the points. A smoothing operation is performed by taking an average of every three consecutive points and plotting these average values. The averaging is also done by the 650 computer. Two output sheets are obtained: one is the sheet with the counts corrected for decay, background, and interchannel normalization; the other is the sheet with every three of these points averaged.

Summary

Critical bucklings, reflector savings, power distributions, and neutron ages can be computed from information provided by plots of neutron distributions in reactors. These plots can be produced quickly and accurately by using well-known activation techniques combined with automation and machine computation. The use of automatic equipment enables more efficient operation of our critical facilities because it permits more efficient use of scientific personnel, enables more intelligent planning of experiments, and improves over-all accuracy, thus allowing a more refined comparison to be made with theory. The release of several calculators from routine calculations permits other calculations on problems not readily adaptable to machine computation. There is a saving in computing-machine time, too, because the experimental data in several instances have shown that certain assumptions can be legitimately made without appreciable errors in the results. Perhaps the greatest and most important result has been that experimental information is provided rapidly, making it available when it is most needed.

* * *

The thoughtful planning and capable work of Mr. Thomas J. Kikta and his group in carrying out the successful installation of the equipment are gratefully acknowledged. Early discussions with Dr. Edith Fehr of the Knolls Atomic Power Laboratory, Mr. Roland Suares of the Westinghouse Electric Corp., Mr. H. S. Bright of the Bettis Plant, and Messrs. R. V. Brown and J. A. McDonald of International Business Machines were especially helpful in formulating the plans for the counting system.

The author is indebted to the U. S. Atomic Energy Commission and the Westinghouse Electric Corp. for permission to publish this work.

BIBLIOGRAPHY

1. R. T. Frost, E. B. Fehr, NUCLEONICS **14,** No. 3, 84 (1956)
2. R. J. Preston, The MTR automatic wire scanner, IDO-16243 (1955)
3. N. F. Moody, W. D. Howell, W. J. Battell, R. H. Taplin, *Rev. Sci. Instr.* **22,** 439 (1951)
4. J. B. Birks, "Scintillation Counters" (McGraw-Hill Book Co., Inc., New York, 1953)

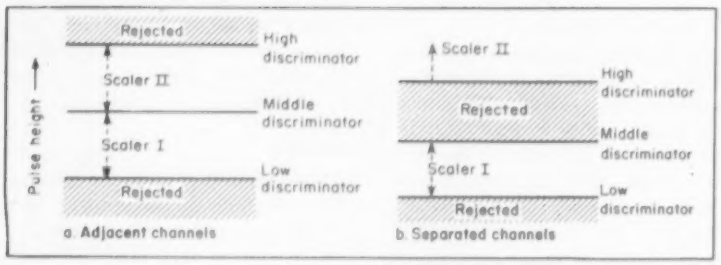


FIG. 1. Schematic diagram of operation with adjacent and with separated channels

Separated Channels Improve Liquid Scintillation Counting

By MONTE BLAU
Department of Biochemistry Research
Roswell Park Memorial Institute
Buffalo, New York

The addition of a single switch to the circuit of an existing dual-channel liquid scintillation counter makes it possible to improve the separation of isotope pairs with overlapping energy spectra. The improvement is achieved by operating with separated channels instead of the present adjacent-channel pattern.

Commercially available dual-channel liquid-scintillation counters sort pulses by height according to the scheme shown in Fig. 1a. Three discriminators divide the spectrum into two adjacent channels with the middle discriminator serving as the top of the bottom channel and also as the bottom of the top channel. This arrangement is satisfactory for counting isotope pairs with as little spectral overlap as H^3 (0.018 Mev) and C^{14} (0.15 Mev), but when counting pairs with closer energies, it is helpful to be able to eliminate the region of maximum overlap by counting with two independent channels.

The addition of a fourth discriminator would accomplish this but only with a substantial increase in expense and complexity. However, by a simple modification of the existing three-discriminator models, it is possible to achieve channel separation as shown in Fig. 1b. Here the lower channel lies between the settings of the low and middle discriminators and the upper channel is above the high discriminator with no upper level (that is, it is an integral discriminator).

The simplified block diagram of Fig. 2 shows how the addition of a switch accomplishes this on the Technical Measurement Corp.* LP-2A counter. The indicated switch is the only change necessary and it permits operation in the normal adjacent-channel position or with separated channels. In the normal adjacent-channel position, pulses above the low discriminator setting are counted in scaler I. If the pulse is high enough to trip the middle discriminator, the anticoincidence circuit keeps the pulse out of scaler I. The pulse is then recorded in scaler II unless it is high enough to trip the high discriminator and be rejected by the upper anticoincidence circuit. In the separated-channel position, pulses passing the middle discriminator are kept out of scaler I as before, but they do not record in scaler II unless they are high enough to pass the high discriminator. A similar simple change will convert other three-discriminator instruments to this mode of operation.

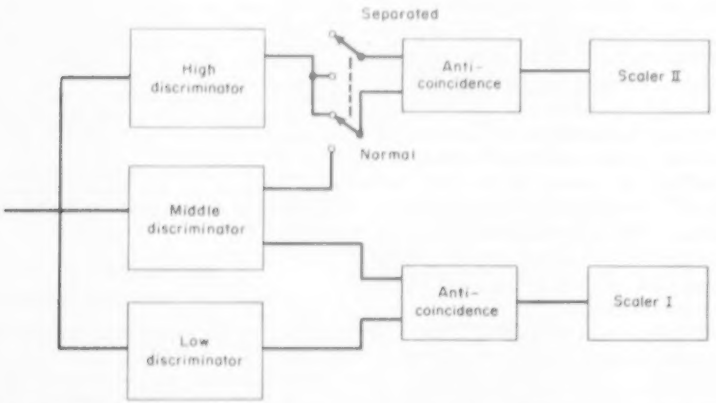


FIG. 2. Block diagram of dual-channel scintillation counting discriminator arrangement showing switch for changing mode of operation

Separated-channel operation has been used for accurate counting of samples containing C^{14} (0.15 Mev) and I^{131} (0.61 Mev, 87%; 0.34 Mev, 9%; 0.25 Mev, 3%). Figure 3 shows the fraction of the integral C^{14} and I^{131} counts

* Technical Measurements Corp., New Haven, Conn., has since made this modification on all of their LP-2A counters. Packard Instrument Co., LaGrange, Ill., will make equivalent changes in their instrument on request.

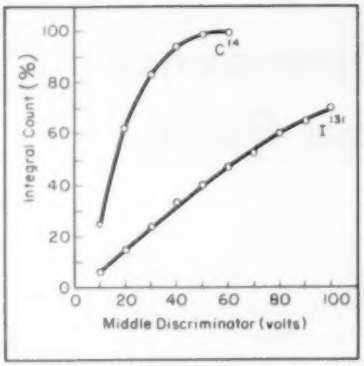


FIG. 3. Curves of low channel counts used for selecting optimum operating conditions

falling between the low discriminator (set at 4 v) and the middle discriminator, as the middle discriminator is varied up to the maximum of 100 v. With adjacent channels, counting with all of the C^{14} in the lower channel requires a middle discriminator setting of 60 v, thereby putting as many I^{131} counts in the lower channel (4–60 v) as appear in the upper channel (>60 v). The C^{14} counts must therefore be measured against a high background of I^{131}. The minimum overlap which could be achieved with adjacent-channel operation would be with a middle discriminator setting of 27.5 v when there would be 22% of the C^{14} counts in the upper channel (>27.5 v) and 22% of the I^{131} counts in the lower channel (4–27.5 v).

With separated channels, it is possible to count with as little as 15% of the I^{131} in the lower channel (4–20 v) and, by rejecting the region from 20–60 v, not have any C^{14} in the upper channel (>60 v). The lower channel would contain 60% of the C^{14} counts and the upper channel 50% of the I^{131}. The exact choice of settings would depend on the amount and ratio of C^{14} and I^{131} in the sample. Low I^{131} overlap into the C^{14} channel is particularly important with samples containing high I^{131} to C^{14} ratios. Photomultiplier voltages high enough to give adequate efficiency for C^{14} put a substantial fraction of I^{131} counts above the 100-v maximum discriminator setting, requiring operation with no upper level in the upper channel with either counting mode.

* * *

The author wishes to thank Mr. George Utting for valuable aid and advice. This work was supported by the U. S. Atomic Energy Commission (contract AT-(30-1)-1771).

University of Michigan laboratory technicians handle a low-level radioactive sample in the "hot storage" area. The standard Corning shield is 36 inches thick. Corning will also build any custom shield you want.

The radiation window that gives you a view as clear as this costs the least

If you were actually standing outside the University of Michigan's radiation cave number 2—instead of looking at a screened reproduction of a photograph—you'd be able to see clearly any small detail you wanted to.

Anything you could read with your naked eye you could just as easily read through this yard-thick, almost water-white Corning Radiation Shielding Window.

It's made of 3.27 density Corning Code 8362 lead glass that inch-for-inch matches dense concrete for shielding. Nonbrowning Code 8362 doesn't lose transparency with time.

You need no fluid shielding medium with the Corning window. There's nothing to replace or recondition. It comes as a "package"—ready for insertion in your cell wall.

Nonbrowning, nondiminishing shielding, resistance to abrasion plus the most shielding per dollar of any window, all make Corning Code 8362 the most economical shield you can buy.

BRIEF SPECIFICATIONS

Code 8362 has a refractive index of 1.594 and an internal transmittance of 93% in 5" thickness with sodium lighting. It's chemically stable, indifferent to moisture, and optically clear.

It's cerium stabilized, resists browning and recovers rapidly from tinting. You can order single-piece thicknesses to 12" and sizes up to 100" x 70". We'll make the window you need to your specifications.

For detailed information, write to us.

FOR LEAD AND STEEL WALLS

Corning Code 8363, a 6.2 density glass, meets the requirements of lead and steel walls, or backs up Corning Code 8362 in 300 lbs. per cu. ft. concrete walls. Combinations of Corning Shielding Glasses have been installed in windows with a total glass path of over 200 density inches.

Write for Technical Bulletin No. PE-50, "Radiation Shielding Glasses by Corning." It covers properties and characteristics.

Technical Products Division

CORNING GLASS WORKS

16-4 CRYSTAL STREET, CORNING, N. Y.

Corning means research in Glass

SCINTILLATION PHOSPHORS

introducing

NE 400

for new simplicity and efficiency in neutron detection

This is a new type boron polyester composition with Zns (Ag) activator.

- Excellent neutron to gamma response ratio (100 to 1 for Po-Be)
- High detection sensitivity
- Supplied in thin disks of various diameters

PLASTIC PHOSPHOR

NE 102

Our new plastic scintillator possesses an extremely high light output (60–65% of anthracene). It provides superior performance at high counting speed, with maximum efficiency and greatest economy. Available in any size or shape.

LOADED LIQUID SCINTILLATORS

In bulk or encapsulated containing Pb (for x-ray sensitivity), Gd, B or Cd for neutron detection, and Scintillating Gels for internal counting.

SCINTILLATION CHEMICALS

Wide range of highest purity materials.

Our INSTRUMENT DIVISION offers the Mark VI, VIA, and IX SCINTILLOMETERS for geophysical applications.

where research COUNTS

NUCLEAR enterprises ltd.

1750 Pembina Highway
WINNIPEG 9, CANADA

Associate Co:
Nuclear Enterprises (G.B.) Ltd.,
Bankhead Medway, Sighthill, Edinburgh 11, Scotland.

Temperature Dependence of Photomultiplier Gain

By FRANK E. KINARD
Savannah River Laboratory
E. I. du Pont de Nemours and Co., Inc.
Aiken, South Carolina

The energy sensitivity of scintillation counters makes possible gamma-ray spectroscopy wherein pulse height can be correlated with photon energy. In such applications, the gain stability of the instrument is of primary importance. Ambient temperature, one of several factors that may influence the gain (*1*), might affect:

1. The photoelectric efficiency of the photocathode of the photomultiplier.
2. The secondary emission ratio of the dynodes.
3. The magnitude of the light flash emitted by the crystal.

We have investigated each of these effects.

Experimental Setup

The gain stability of photomultiplier tubes exposed to varying temperatures was measured by recording the output pulse height of the tubes as a function of temperature when they were exposed to a light pulse of constant amplitude.

The photomultipliers were tested in a constant-temperature air bath, the temperature of which can be set and controlled to within $\pm 1°$ C in the range from -20 to $+60°$ C. Light signals passed through the wall of the air bath by way of a Lucite cylinder 7 in. long and 2 in. in diameter. The light signals originated in a NaI(Tl) phosphor exposed to a 0.125-μc Cs^{137} source. The photomultiplier was clamped in position in contact with the end of the

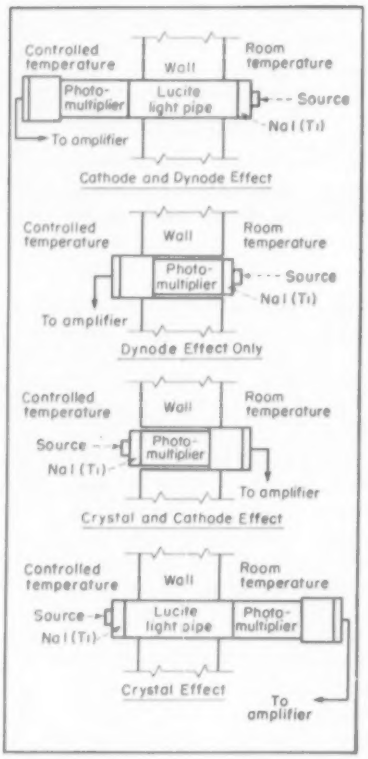


FIG. 1. Various arrangements of constant-temperature air bath used to determine how temperature affects photomultiplier

Other Studies of Temperature Dependence

Ball *et al.* (*4*) studied temperature effects on RCA-6199 and DuMont-6291 tubes and NaI(Tl), anthracene, stilbene, and plastic scintillators, over the range 5°–40° C.

The scintillator coefficients (change in pulse height) were found to vary from anthracene. The coefficients themselves are functions of temperature.

Photomultiplier coefficients varied from -0.27 to -0.42 for 6199 tubes and from -0.2 to -0.28 for 6291 tubes. The coefficients were independent of tube high voltage over the range 650–950 volts.

Herold *et al.* (*1*) suggest a temperature-compensating circuit for the range 25°–60° C. A circuit using a thermistor was designed and placed in the output stage of the detector preamplifiers. Pulse-height change was 5% or less at up to 55° C.

Tests of scintillation-probe monitors at the Savannah River Plant showed that most of the temperature coefficient was due to the preamplifier rather than the tube and crystal. The preamplifier germanium diode was thought to be a major temperature-sensitive component because its back resistance decreases with increasing temperature. Temperature-gain stability of the preamplifier was much improved after removal of the diode. Probe gain with the diode removed was measured a second time and showed a drop of $\frac{1}{3}$ in gain with increasing temperature.

EQUIPPED TO PRODUCE

Nuclear Fuel Elements and Components

We are in the midst of an important growth designed to meet the expanding needs for nuclear fuel elements. Vital to this growth is the selection of qualified personnel. We need more engineers to design, procure, and set up special equipment like this high temperature hydrogen atmosphere furnace. The knowledge and skills of the engineer are a basic part of our production operations. Ability to design proper experiments for obtaining data to use in production processes is a fundamental prerequisite to the fabrication of fuel elements.

Only through human engineering skills, commensurate with our depth of production facilities, is growth possible. As an important part of our current expansion program, we need more bright, aggressive men with scientific training and experience in mechanical, metallurgical or chemical engineering. Qualified personnel and complete, modern facilities are further evidence that the Nuclear Products Division of Metals & Controls Corporation is able to translate scientific data and experimental results into production know-how. Utilizing this capability of scientific production, Nuclear Products Division has established a leading position in the nuclear fuel element field.

Let us assist in your reactor program by supplying information on fuel element fabrication based on your specifications and designs. For complete details, write for our brochure, Fuel Element Fabrication, or address your inquiry directly to our Manager of Contract Administration.

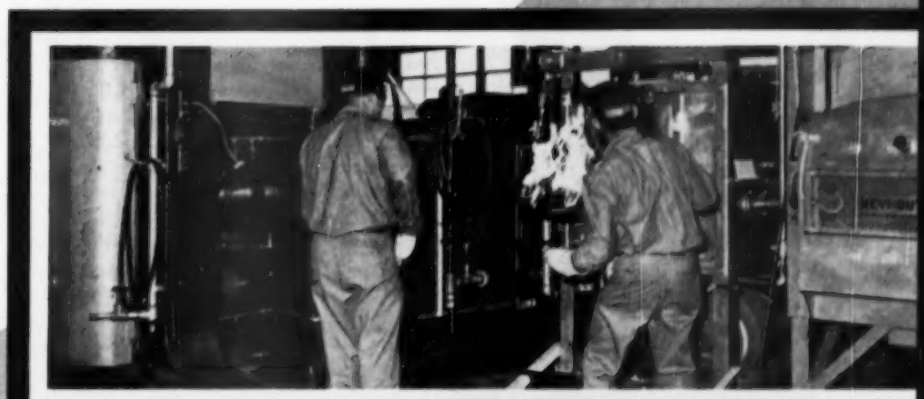
METALS & CONTROLS CORPORATION

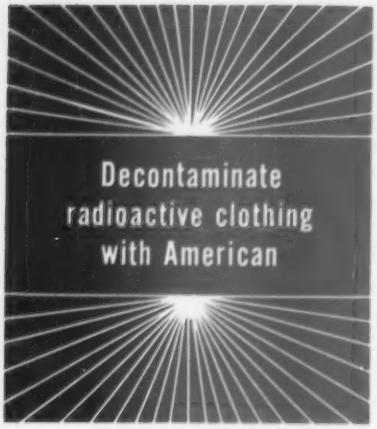
Nuclear Products Division

1304 Forest St., Attleboro, Mass.
Telephone: Attleboro 1-2800

Our newly published booklet, "Your Opportunities at Metals & Controls Corporation," gives detailed information about joining this forward moving firm.

Write or call our Employment Director for your copy today.





world's largest manufacturer of laundry and dry cleaning equipment

A complete planning service is available from The American Laundry Machinery Company to help nuclear plants establish efficient decontamination and laundry facilities.

This service, based on more than 89 years' experience in the textile maintenance field, includes detailed drawings, floor plan layouts and complete specifications for each installation. Finished plans show the location, size and floor loads of all machines. Solvent, water, steam, compressed air and electrical requirements are computed, together with size and location of all service connections. Every detail necessary for an efficient, space-saving clothing decontamination department is included.

In addition, American's continuous assistance is always available. Individual representatives, service engineers, local offices and repair depots are strategically located in 84 communities throughout the country.

For complete information on how American serves the atomic energy field, send for Bulletin No. 2642.

You can expect more from

American

The American Laundry Machinery Company, Cincinnati 12, Ohio

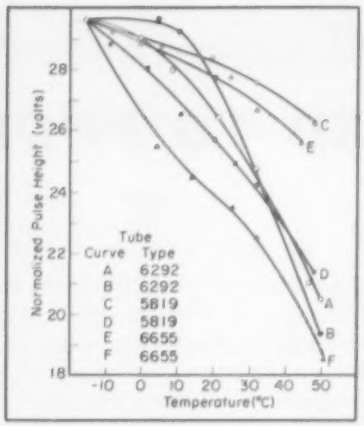


FIG. 2. Photomultiplier gain as function of temperature of photocathode and dynodes

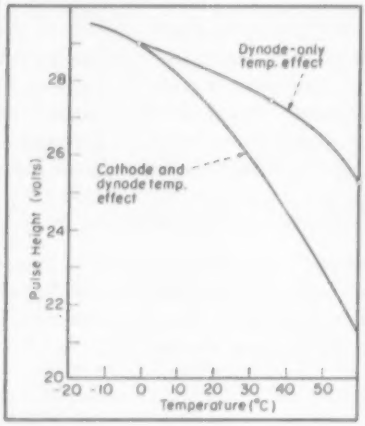


FIG. 3. Temperature dependence of gain of 6292 photomultiplier as function of cathode and dynode temperature and of dynode temperature only

light pipe, but no optical coupling between the two was used. The equipment arrangement is shown in Fig. 1.

To eliminate temperature effects in the dynode bleeder chain, this unit was mounted outside the air bath. The high voltages for the the photomultiplier were led into the tube socket by a shielded cable.

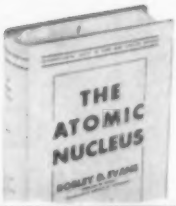
The multiplier-anode signals were fed to a 204-B linear amplifier.* The amplifier output was examined with a Model 510 differential pulse height analyzer* and a scaler. The photomultiplier high voltage was obtained from a Model 312 supply.* This system showed negligible drift in an 8-hr period after a warm-up time of at least 24 hr.

The mean height of the photopeak of

* Atomic Instrument Co., Cambridge, Mass.

McGraw-Hill

BOOK NEWS



THE ATOMIC NUCLEUS

Here is a broad coverage of nuclear physics, combining experimental and theoretical approaches in one useful reference for workers in related fields. Methods of determining nuclear moments are thoroughly discussed and there is a complete treatment of statistical fluctuations and theory of errors. Begins each topic at introductory level and progresses into advanced areas. By Robley D. Evans, Prof. of Physics, Mass. Inst. of Tech. 972 pp., 330 illus., $14.50

MODERN CHEMISTRY FOR THE ENGINEER AND SCIENTIST

JUST PUBLISHED. In this book, world-renowned specialists give you fresh concepts and advanced methods for making chemistry meet today's engineering requirements. From developments in the use of isotopic tracers and of photochemistry, to concise reports of progress in contact catalysis and in the petrochemical industry—a wide range of topics is covered. Edited by G. Ross Robertson, Prof. of Chem., U. of Cal. 442 pp., 162 illus., $9.50

MODERN PHYSICS FOR THE ENGINEER

Nineteen eminent scientists explore with you the basic physical sciences on which our engineering society is built. Written especially for the engineer, the book shows the interesting developments, achievements, and methods used in the various "pure" sciences. Three broadly-defined sections of the book cover the laws of nature, the world we live in, and the communication of information. Edited by L. N. Ridenour, Lockheed Corp. 490 pp., 211 illus., $7.50

MODERN MATHEMATICS FOR THE ENGINEER

JUST PUBLISHED. Presents refined methods of analysis and calculation—easier ways to handle both simple and complicated design problems with greatest efficiency. Covers mathematics of probability, theories of prediction, games, dynamic programming, etc. By a group of specialists. Editor, Edwin Beckenbach, U. of Cal. 516 pp., 97 illus., $7.50

SEE THESE BOOKS 10 DAYS FREE

McGraw-Hill Book Co. Dept. Nu-4
327 W. 41st St., N.Y.C. 36

Send me book(s) checked below for 10 days' examination on approval. In 10 days I will remit for book(s) I keep, plus few cents for delivery costs and return unwanted book(s) postpaid. (We pay delivery cost if you remit with this coupon—same return privilege.)

- ☐ Evans—Atomic Nucleus, $14.50
- ☐ Robertson—Mod. Chem. for Eng., $9.50
- ☐ Ridenour—Mod. Physics for Eng., $7.50
- ☐ Beckenbach—Mod. Math. for Eng., $7.50

(PRINT)

Name.....

Address.....

City.....Zone....State.....

Company.....

Position.....

For price and terms outside U. S., Nu-4 write McGraw-Hill Int'l., NYC.

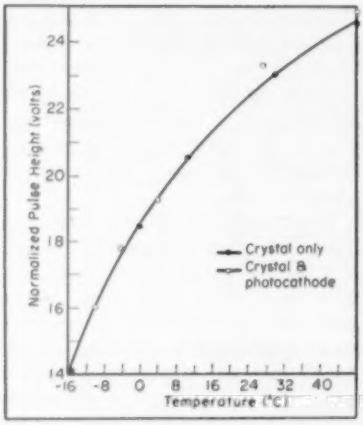


FIG. 4. Gain as function of crystal temperature and of crystal and cathode temperature. Data is normalized to −16° C

Cs^{137} was taken as a measure of photomultiplier gain at constant voltage and constant amplifier gain. This height was determined by taking a series of counts at 1-volt bias intervals, with a window width of 1 volt. The midpoint of the channel or channels registering the highest count was taken as the mean photopeak height.

The energy resolution of the system was 15–20% but showed no change with photomultiplier temperature.

Two DuMont 6292, two RCA 5819, and two RCA 6655 photomultipliers were tested in this way.

The results are displayed in Fig. 2, which shows the pulse height of the photopeak as a function of tube temperature. The temperatures are those recorded by an iron-constantan thermocouple taped to the photomultiplier envelope near the photocathode. These curves were normalized to the same pulse height at −18° C.

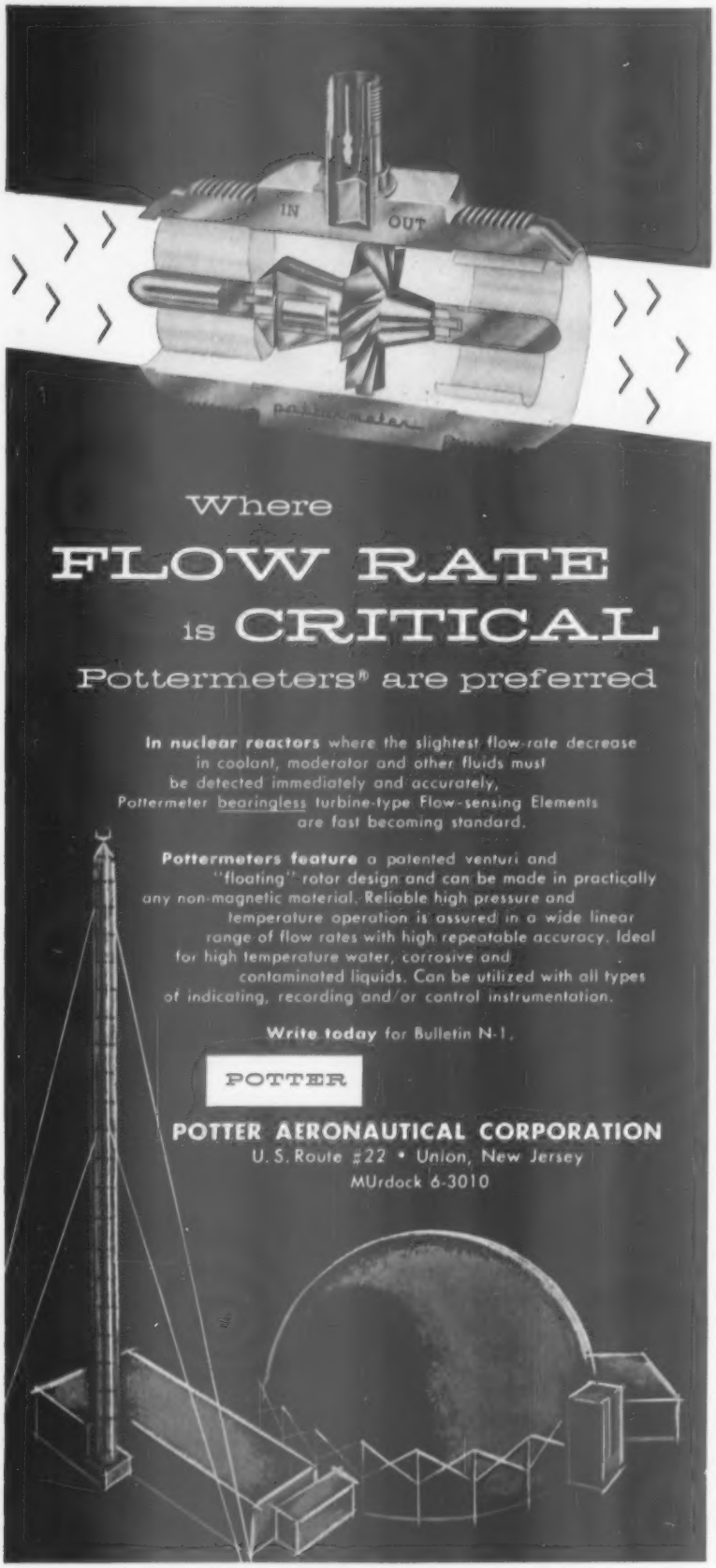
Figure 2 shows that there are large differences in temperature sensitivity between two tubes of the same type.

When sufficient time was allowed for the photomultiplier to come to temperature equilibrium, the curve for any tube was reproducible and showed no hysteresis. When the air-bath temperature was changed by 20° C, the temperature of the glass envelope reached a new value in about 80 min, but the tube gain did not reach equilibrium for about 150 min.

Dynode Temperature

To determine whether the temperature-sensitive element in photomultipliers is the cathode, or the dynode

FENN
Metal Forming
Equipment
Swaging Machines
Rolling Mills
Turks Heads
Draw Benches
Core of Your Nuclear Planning
FENN PRECISION ROLLING MILLS are made in a complete range of sizes and types for laboratory, pilot run and production. They are designed and built to meet the requirements of nuclear metallurgy, including the newest and toughest metals. They can be supplied in both vertical and horizontal types with complete instrumentation for remote control and hooding where necessary.
FENN ROTARY SWAGING MACHINES are the invaluable precision production tools for nuclear metal forming ... hot or cold ... without producing chips. A complete range of sizes with capacities from ½" to 6" diameter. Models also available for internal reductions and with special length dies. Compact self-contained unit facilitates hooding.
FENN DRAW BENCHES AND TURKS HEADS—Fenn makes both hydraulic and mechanically actuated draw benches with capacities from 2,000 to 40,000 pounds pull. Variable drawing and return speeds to fit your specific requirements. Fenn Turks Heads, with infinite adjustment of rolls, are a valuable accessory to draw benches for producing almost limitless shapes in wire, rod, or tube.
For engineering services or literature, write
NUCLEAR MACHINERY DIVISION
FENN
THE FENN MANUFACTURING COMPANY, 702 FENN ROAD, NEWINGTON, CONN


IN
OUT
Where
FLOW RATE
is CRITICAL
Pottermeters® are preferred
In nuclear reactors where the slightest flow-rate decrease in coolant, moderator and other fluids must be detected immediately and accurately, Pottermeter bearingless turbine-type Flow-sensing Elements are fast becoming standard.
Pottermeters feature a patented venturi and "floating" rotor design and can be made in practically any non-magnetic material. Reliable high pressure and temperature operation is assured in a wide linear range of flow rates with high repeatable accuracy. Ideal for high temperature water, corrosive and contaminated liquids. Can be utilized with all types of indicating, recording and/or control instrumentation.
Write today for Bulletin N-1.
POTTER
POTTER AERONAUTICAL CORPORATION
U.S. Route #22 • Union, New Jersey
MUrdock 6-3010

structure, or both, the experiment was repeated with the tube base and socket of a 6292 tube inside the constant-temperature air bath and with the photocathode end of the bulb outside (see Fig. 1). In this arrangement, only the temperature of the tube base could be varied at will.

The results are shown in Fig. 3. This curve shows the gain of the tube as a function of the temperature of the tube base only. The photocathode end of the bulb was at 27° C when the base temperature was 0° C and rose to 33° C when the base temperature was at 50° C. For comparison, the gain as a function of photocathode and dynode temperature for this same multiplier is included.

The difference in magnitude of the two effects suggests that the temperature of the dynodes is the determining factor in the temperature dependence of the gain. Presumably the dynodes will not reach the same temperature as the tube base if a temperature differential between tube base and envelope exists.

Photocathode Temperature

The results in Fig. 3 leave some doubt as to the contribution of the photocathode to temperature dependence.

To isolate the effect of the photocathode, two additional experiments were performed. In the first, the temperatures of both crystal and photocathode were varied. In the second, only the crystal temperature was varied. (See the experimental arrangements in Fig. 1.) The difference between the two sets of data should reflect the effect of the photocathode.

The results of the two experiments are shown in Fig. 4. The fact that there is no significant difference between the two sets of data implies that there is no change of photocathode characteristics with temperature. This observation is supported by previous results (*2*), which showed no change in photocathode sensitivity over this same temperature range.

From these results, it may be concluded that:

1. Photomultiplier gain decreases up to 40% with increasing temperature in the range −15° to +50° C.

2. The temperature dependence is associated with the temperature of the dynode structures.

Using 5819 and 6292 tubes, a pulsed light source, and optical filters to isolate narrow regions of the spectrum, Seliger and Ziegler (*3*) have found an

increase in photomultiplier gain with increasing temperature in the range −20° C to +30° C. These results are therefore in disagreement with those reported here. It is possible that a change with temperature of the spectral response of the photocathode could lead to their results.

However, Ball *et al.* (4) have found negative temperature coefficients for the gain of 6199 photomultipliers, using a pulsed light source, in the range 5°–40° C.

Phosphor Temperature

The maximum amplitude of the amplifier output pulse is shown in Fig. 4 to increase with increasing crystal temperature. The scintillation efficiency, which is proportional to the total number of photons per light flash and should be independent of pulse shape, has been reported (*5–6*) to decrease with temperature.

The amplifier used affects the magnitude of the observed crystal temperature dependence because the amplifier is relatively insensitive to pulses having a longer decay time than the *RC* decay time of the amplifier. The light pulse from a sodium iodide phosphor is composed of at least four exponential components, the decay time and relative intensity of each being a function of temperature (*7, 8*). The over-all effect on the decay time is that it is increased as the temperature is decreased.

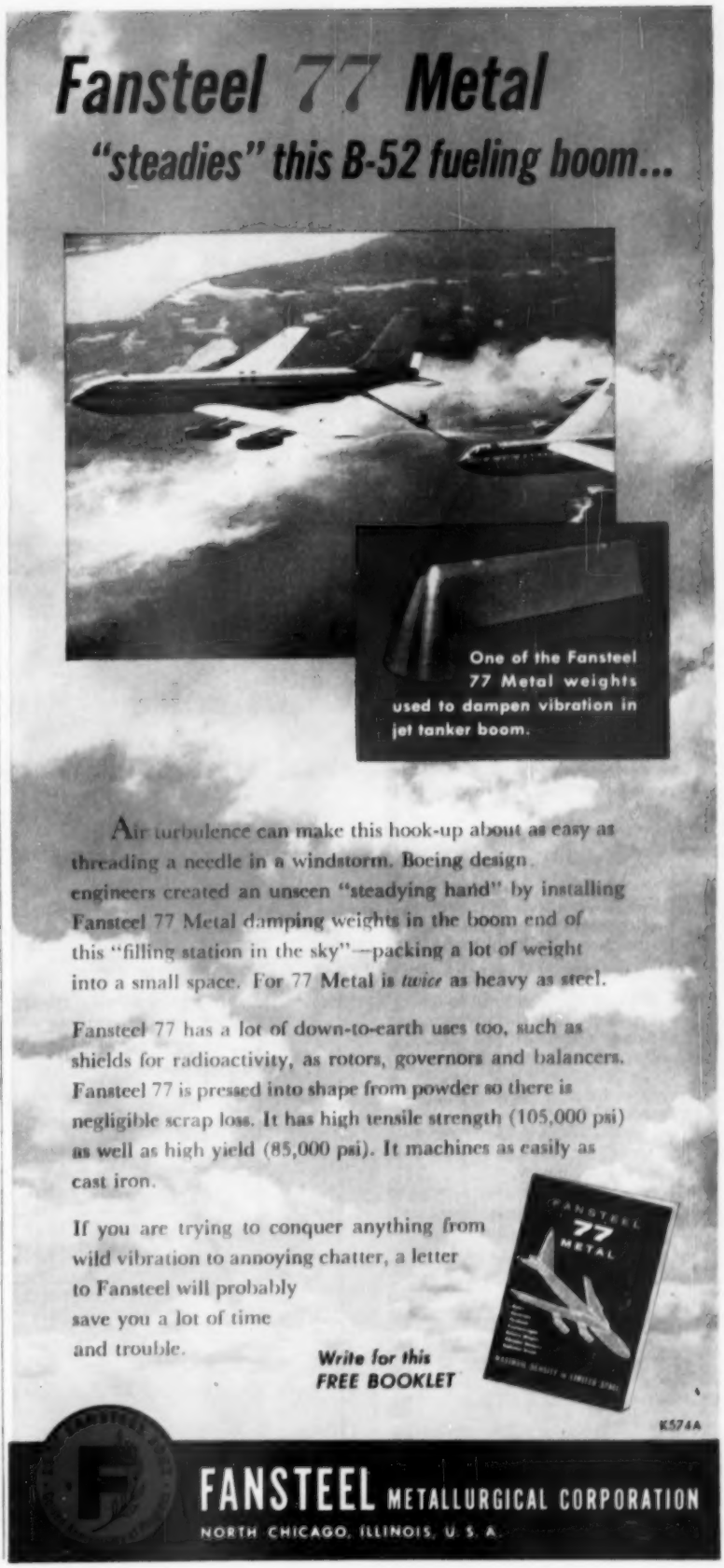
The decay time of the amplifier used to obtain the data shown in Fig. 4 was nominally 0.4 μsec. If the decay time were increased to a nominal 25 μsec, the same crystal gave a negative temperature coefficient of about 0.1%/° C in the range 10°–50° C. Thus the temperature dependence of the crystal may be minimized by proper electronic design.

* * *

The work reported here was done for the U. S. Atomic Energy Commission under contract AT(07-2)-1. Permission to publish is gratefully acknowledged.

BIBLIOGRAPHY

1. T. R. Herold, W. A. Kropp, J. S. Stutheit, DP-47 (1956)
2. R. W. Engstrom, Tube Div., Radio Corp. of America, Lancaster, Pa., private communication
3. H. H. Seliger, C. A. Ziegler, NUCLEONICS **14**, No. 4, 49 (1956)
4. W. P. Ball, R. Booth, M. H. MacGregor, *Bull. Am. Phys. Soc.* **31**, 183 (1956)
5. L. A. Webb, R. F. Johnson, *Phys. Rev.* **98**, 234 (1955)
6. L. A. Webb, USNRDL TR-48 (1955)
7. J. Bonanomi, J. Rossel, *Helv. Phys. Acta* **25**, 725 (1952)
8. E. der Mateosian, M. McKeown, C. O. Muehlhause, *Phys. Rev.* **101**, 967 (1956)


Fansteel 77 Metal
"steadies" this B-52 fueling boom...
One of the Fansteel 77 Metal weights used to dampen vibration in jet tanker boom.
Air turbulence can make this hook-up about as easy as threading a needle in a windstorm. Boeing design engineers created an unseen "steadying hand" by installing Fansteel 77 Metal damping weights in the boom end of this "filling station in the sky"—packing a lot of weight into a small space. For 77 Metal is *twice* as heavy as steel.
Fansteel 77 has a lot of down-to-earth uses too, such as shields for radioactivity, as rotors, governors and balancers. Fansteel 77 is pressed into shape from powder so there is negligible scrap loss. It has high tensile strength (105,000 psi) as well as high yield (85,000 psi). It machines as easily as cast iron.
If you are trying to conquer anything from wild vibration to annoying chatter, a letter to Fansteel will probably save you a lot of time and trouble.
Write for this FREE BOOKLET
FANSTEEL 77 METAL
K574A
FANSTEEL METALLURGICAL CORPORATION
NORTH CHICAGO, ILLINOIS, U. S. A.

Look no further—

if you're looking for

"HIGH PURITY"

fused quartz

LABORATORY WARE

The world's largest producer of fused quartz products can help you with your most critical and exacting needs for your laboratory ware.

Vitreosil® products can be supplied in an unusually large variety of types and sizes. Also fabricated to specification to meet semi-conductor requirements for the production of silicon metal.

TRANSPARENT VITREOSIL

For ultra-violet applications, metallurgical investigations, chemical research and analysis, photochemistry, spectroscopy and physical, optical and electrical research.

Send specifications for your requirements. Please use coupon below.

THERMAL AMERICAN FUSED QUARTZ CO., INC.

18-20 Salem Street, Dover, New Jersey

Please send technical data on

Company

Name & Title

Street

City Zone State

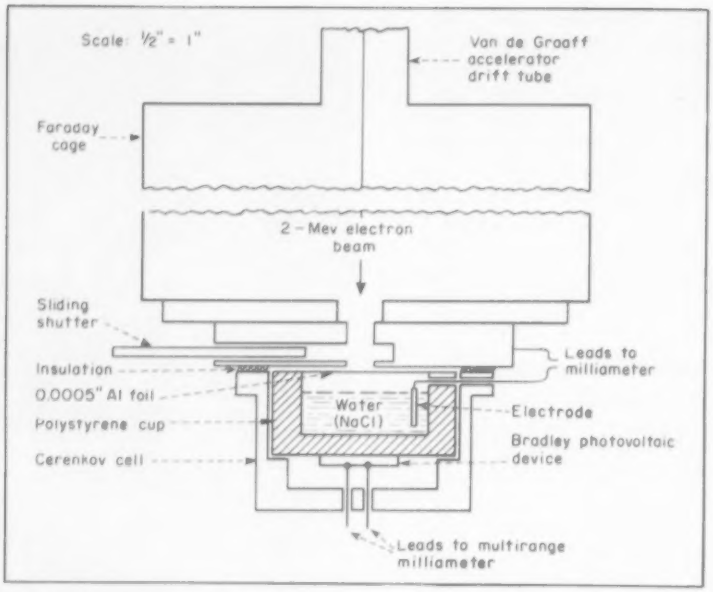


FIG. 1. Arrangement of Cerenkov monitor for measuring 2-Mev electron beam. Beam enters cell through ½-in. hole controlled by ¼-in.-thick aluminum shutter

Cerenkov-Photovoltaic Monitor for High-Intensity Radiation

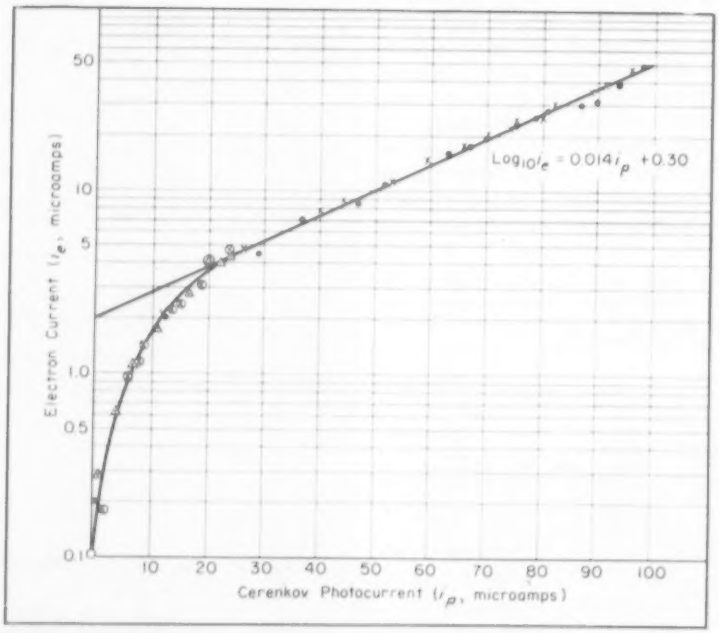


FIG. 2. Relationship of electron-beam current and Cerenkov photoelectric current. Data are plotted for five independent runs

By C. C. THOMAS, Jr., K. H. SUN, and E. A. MARUSICH
Materials Engineering Department
Westinghouse Electric Corporation
East Pittsburgh, Pennsylvania

A high-intensity-radiation monitor has been developed here comprising a Cerenkov cell, a photovoltaic detector, and a milliammeter. It is mechanically and electronically simple. Since, in a reactor radiation field, Cerenkov radiation would be produced by gamma rays but not by neutrons, the device would be useful for measuring gamma flux in a reactor shield.

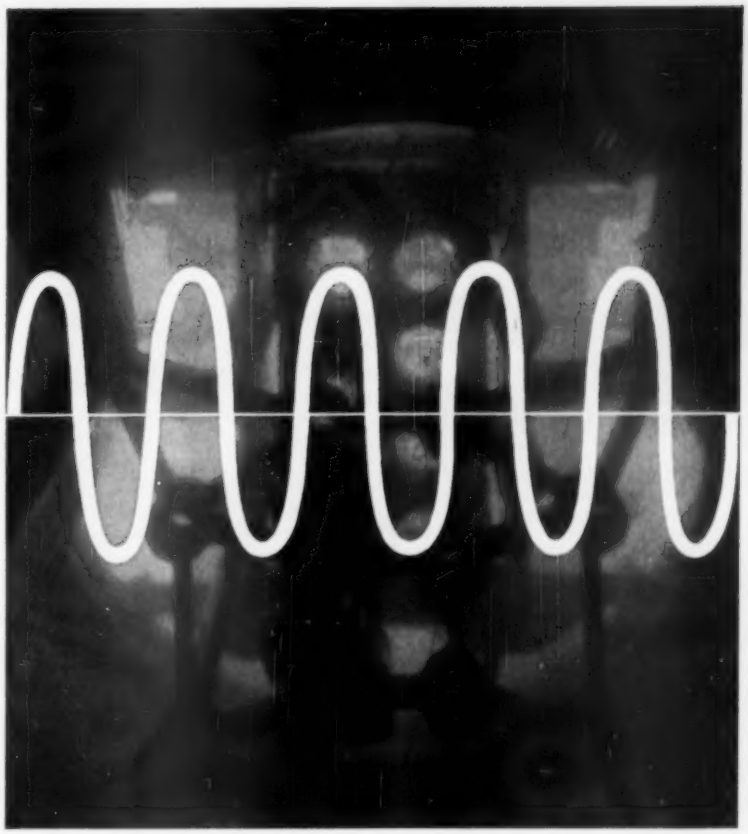
In monitoring high-intensity radiations, such as high-energy electron beams, kilocurie gamma emitters, or spent reactor fuel elements, difficulties are often encountered. Some fluorescent devices using organic phosphors, activated ZnS, fluorescent glass, or scintillating liquids are affected by temperature changes and by long bombardment of intense radiation (10^3–10^{10} rep/sec). Ionization chambers require excessive circuitry. In the case of high-energy electrons, direct measurement of current without a Faraday cage is not possible, because of secondary scattering and air ionization.

It was against this background that the present investigation was aimed at developing a radiation monitor with a simple circuit and a simple mechanical structure, which would not be affected by long bombardment with radiation.

When a charged particle, such as an electron, passes through a transparent medium (either liquid or solid) at a speed v greater than the speed of light in that medium, it loses energy by emitting visible and near-visible radiation, known as the Cerenkov radiation. Since the speed of light in the medium equals c/n, where c is the speed of light in vacuum and n is the refractive index, we have the following condition for the emission of Cerenkov radiation:

$$v > c/n \quad \text{or} \quad v/c \equiv \beta > 1/n$$

A simple liquid, such as water, not colored by radiation, is convenient to use in the present device. Taking 1.33 as the refractive index of water at



WHAT THE MARTIN "GAMMA FACILITY" OFFERS TO NUCLEAR ENGINEERS

The important new Martin Gamma Irradiation Facility is being used to explore the behavior of materials in a radiation environment.

As part of the Martin Nuclear Division Laboratory, this facility is pioneering in the use of high-energy gamma radiation for diversified studies on radiation-induced changes in organic and inorganic materials.

Experimentation in this laboratory runs the gamma gamut from fundamental studies of reaction mechanisms in radiation chemistry to the whole new science of materials development for the space systems of tomorrow.

There are exciting opportunities at Martin in this big new field.

Contact J. J. Holley, Dept. N-04, The Martin Company, Baltimore 3, Maryland.

MARTIN
BALTIMORE

qualifications?

"With the *right* qualifications," says Dr. Frank C. Brooks, Director of the Combat Operations Research Group of Technical Operations, Incorporated, "a scientist who wants to *grow* fits in here. We're a growing research organization with freedom to think, in an atmosphere of creative opportunity. Right now, at Fort Monroe, Va. and Monterey, Calif., we're looking for an

Applied Mathematician or Logician

who combines strong backgrounds in logic and mathematics, with a knowledge of computer logic and experience in computer applications. We also need an

Experimental or Theoretical Physicist

preferably on the Ph.D. level with two years of experience beyond the degree.

The positions at Fort Monroe are on research and analysis teams tackling theoretical problems in military organization and tactics, using combat models and war games. At Monterey, the emphasis is on the experimental study of combat, using the techniques of design and analysis of experiments and high speed computing."

Address:
ROBERT L. KOLLER
Operations Research Group

tech/ops

TECHNICAL OPERATIONS, INCORPORATED

South Avenue
Burlington, Massachusetts

an arbitrarily chosen wavelength, 4,000 Å, it follows that an electron with $\beta > 0.75$ gives rise to Cerenkov radiation. This corresponds to an electron energy of 0.26 Mev. It follows that if electrons of this energy or greater (whether obtained directly from an accelerator or a radioisotope or from a secondary interaction of an electromagnetic photon such as an X-ray or γ-ray) are injected into water, visible or near-visible radiation will be emitted. The light is emitted in a cone whose axis is the track of the electron and whose half-angle θ is given by

$$\theta = \cos^{-1}(1/\beta n)$$

For a 2-Mev electron and visible radiation at 4,000 Å, $\theta = 40$ deg. The Cerenkov radiation is monitored with a conventional photovoltaic device.

Experimental

The experimental arrangement is shown in Fig. 1. The atomic radiation, in this case 2-Mev electrons, produces visible Cerenkov radiation in water placed in a polystyrene container. A vessel made of transparent ultrapure fused silica may be preferable to the polystyrene, because the fused silica can be exposed to radiation doses up to 10^9 rep without discoloration.

These visible radiations, which are mostly in the forward direction, then produce a photocurrent in the photovoltaic semiconducting device. This provides a means of measuring the intensity of the original electron beam.

A Bradley Laboratory type of selenium-barrier-layer photovoltaic cell, $1\frac{3}{4} \times \frac{3}{4}$ in., was used. Other photoelectric devices, such as CdS, CdTe, or a photoelectric semiconducting silicon or germanium junction, may also be used.

A small amount of salt was added to the water in the Cerenkov cell, and a metallic electrode was inserted to monitor the electron current coming into the cell, which also served as a Faraday cage. The current was measured with a 2,336-ohm-impedance milliammeter. The same meter was used for measuring the photoelectric current from Cerenkov radiation.

Discussion

The experimental result is given in Fig. 2, showing a linear relationship of Cerenkov photocurrent and electron-beam current.

About 1% of the photocurrent from the Cerenkov radiation was due to

COMPLETE
CUSTOM OR PRODUCTION

METAL FABRICATION

- ASME Code Fabrication
- High Tolerance Machining
- On Time Delivery
- Engineering Service
- Spectroscopically tight welding for systems operating at pressures varying from 60 microns to 10,000 psi, over temperature ranges to 2,000°F.

WE ARE COMPLETELY EQUIPPED TO HANDLE:

Stainless Steel, Carbon Steel, Inconel, Monel, Nickel, Copper, Lead, Aluminum, Titanium, Zirconium

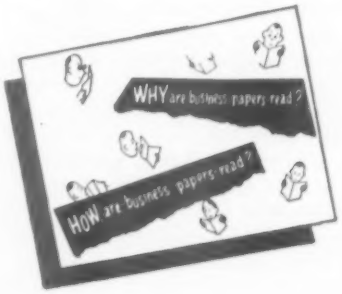
WE HAVE AND CAN FABRICATE:

Tanks, Pressure Vessels, Heat Exchangers, Piping Systems, Glove Boxes, Specimen Holders, Radioactive Transfer Casks, Retorts, Furnaces, Specialty Devices

ADLER'S METAL WORKS

1310 Germantown Ave.
Philadelphia 22, Pa.
STevenson 4-3837

"If we can't perform, we won't bid"



A copy of this quick-reading, 8-page booklet is yours for the asking. It contains many facts on the benefits derived from your business paper and tips on how to read more profitably. Write for the "WHY and HOW booklet."

McGraw-Hill Publishing Company, Room 2710, 330 West 42nd St., New York 36, N. Y.

FILM BADGE SERVICE

For Beta:

- Doses measured from 10 mrep to 100 rep.
- Body or wrist badges supplied.

For Gamma & X-Ray:

- Sensitivity—as low as 10 mr per week.
- Dose Range—10 mr to 500,000 mr.
- Energy Range—50 KVP X-rays to 3 Mev gamma rays. Several filters used to estimate effective energy.

For Neutrons:

- Fast and slow neutron exposures differentiated by cadmium shield.
- Proton tracks greater than 4 grains in length observed at 900X magnification.
- Enough film area examined to measure average weekly doses of 50 mrem throughout one year to within 10 per cent.

- *Professional attention to each evaluation.*
- *Permanent legal records of each film.*
- *Positive x-ray identification of film in badge.*

HEALTH PHYSICS SERVICES, INC.

1111 Low St., Baltimore 2, Md.

METER-RELAYS

FROM 0-5 MICROAMPERES-UP

Ruggedized - Sealed, Black Bakelite or Clear Plastic Cases

D'Arsonval meters with locking contacts for sensitive and accurate control or alarm.

Model 461-C, 10-0-10 Ua DC **$83.25**

TRIP POINT ADJUSTABLE to any point of scale arc. Sensitive to changes as little as 1%. One contact on moving pointer. The other on adjustable pointer. When pointers meet, contacts close and lock. Holding coil wound on moving coil. Locking is electro-magnetic. Manual or automatic reset. Spring action kicks contacts apart.

Ranges: From 0-5 microamperes, 0-5 millivolts or 0-300°F up.

Standard Contact Rating 5 to 25 milliamperes DC. Can be up to 100 milliamperes DC.

Ruggedized-Sealed metal cases, 2½", 3½" or 4½" round, shock-mounted movement, gasket-sealed.

Black Bakelite case, 4½" rectangular.

Clear Plastic cases, 2½", 3¾" or 4½" rectangular.

Model 255-C, 0-10 V DC **$42.50**

Panel meters and indicating pyrometers also in ruggedized-sealed, black bakelite or clear plastic cases. Write for new 40 page Catalog 4A on meter-relays, meters, pyrometers and automatic controls.

Assembly Products, Inc., Chesterland 28, Ohio. HAmilton 3-4436 (West Coast: P.O. Box XX, Palm Springs 28, Calif.) Booth 1323, Design Engineering Show, May 20–23.

X-rays rather than to the direct electron beam. This dark current was measured when the electron shutter was closed and no electrons entered the cell.

From the straight line in the electron-current region of 5–50 μa, the following relationship is derived

$$i_p = 71 \log_{10} i_e - 21$$

where i_p is the photocurrent from Cerenkov radiation due to electrons corrected for X-rays, in microamps, and i_e is the impinging-electron current in microamps. The constants of this equation vary with experimental set-up, and are reproduced within 5% in the present conditions.

The logarithmic response to beam intensity is very useful when a wide intensity range is being used. This behavior is the result of the logarithmic dependence of the photocell voltage upon light when used with a high-impedance load. If the short-circuit current had been measured, this would have been proportional to the Van de Graaff current.

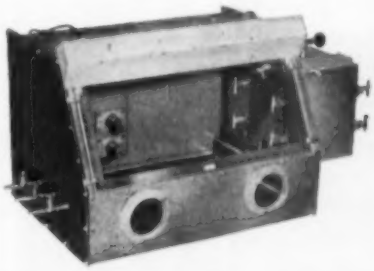
Even though the measurement was carried out with a high-energy electron beam, the device may be easily adopted for X-rays and gamma rays of high intensity where visible Cerenkov radiations exist. It is possible that the photovoltaic device may be coated with an insulating transparent film, so that it may be immersed directly in the Cerenkov liquid cell for expediency. It is also possible that a certain spectrum shifter, immune to radiation damage, may be added to water or liquid to "shift" Cerenkov radiation in the u-v-region to the region where photovoltaic devices are most sensitive.

Since Cerenkov radiation is produced only when the speed of the charged particles is greater than the speed of light in the medium, it follows that charged nuclear particles directly derived from slow or fast neutrons (of the order of a few Mev) will not emit Cerenkov radiation. This is because the speed of these charged heavy particles is much smaller than that of light in ordinary mediums. On the other hand, electrons derived from gamma rays in a reactor usually have a higher speed than the speed of light in ordinary mediums and can be detected by the present method. In this way, the present device detects only gamma rays and no neutrons in a reactor. This discriminating action should be particularly useful in measuring gamma flux in a reactor shield.

Kewaunee

Controlled Atmosphere

GLOVE BOX



A low-cost "laboratory" for hazardous or high purity materials

For projects requiring controlled, uncontaminated atmosphere, the portable Kewaunee CBR system is ideal.

It operates with a slight positive pressure of any selected environmental atmosphere and can be used singly or connected with other units to form a series of totally enclosed laboratories.

The Kewaunee Controlled Atmosphere Glove Box is equipped with an all-welded interchange compartment which serves as an introductory air lock.

The basic CBR unit is made of volume-produced, stainless steel parts and so is remarkably low in cost. And you can order many accessories to adapt it to your particular needs.

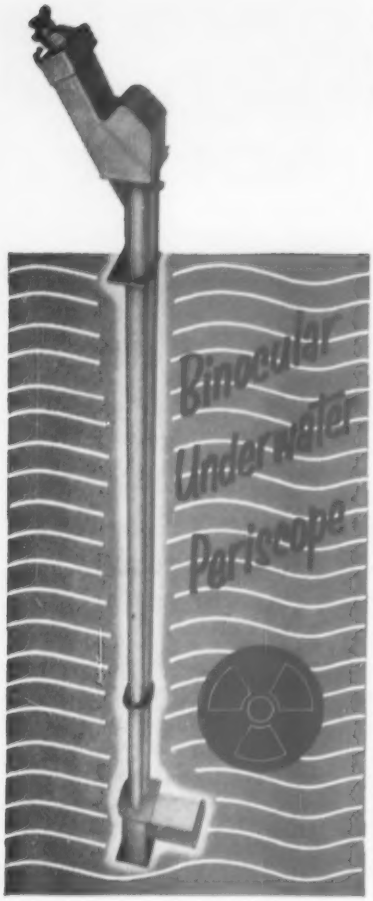
WRITE FOR *FREE* DETAILED CATALOG.

Kewaunee

KEWAUNEE MFG. CO.

5083 S. Center St., Adrian, Mich.

REPRESENTATIVES IN PRINCIPAL CITIES



An industrial periscope is very often the answer to hard-to-get-at, underwater, hazardous location or Hot-Spot remote control observation. Ideal for use where heat, pressure or Hot Cell radiation are problems . . . the periscope offers unsurpassed clarity and definition, true color, and a long, maintenance-free service life. Attachments are available for photo recording all viewed material.

With our wide experience in this field, we probably have a design to fit your viewing problem. Send for Bulletin 301

KOLLMORGEN
Optical
CORPORATION
NORTHAMPTON, MASS.

Improved Molybdenum Separation Procedure

By E. M. SCADDEN
Chemical Technology Division
U. S. Naval Radiological Defense Laboratory
San Francisco, California

Molybdenum is often used as a fission monitor* in fission-yield studies because of its high and well established fission yield.

The classical radiochemical procedure for determining molybdenum activity in fission-product mixtures is somewhat involved and time-consuming. The procedure can be shortened without loss of radiochemical purity and with considerable saving in time, particularly if a number of analyses are to be performed at once.

The classical method† consists of the following steps:

1. Precipitating molybdenum (VI) with α-benzoin oxime and washing the precipitate twice with water or dilute acid.
2. Destroying the precipitate and converting the molybdenum into the insoluble molybdic oxide with fuming nitric acid and perchloric acid.
3. Dissolving the molybdic oxide and scavenging with ferric hydroxide by adding ferric ion and ammonium or sodium hydroxide.
4. Repeating steps 1 through 3.
5. Precipitating and mounting the molybdenum as lead molybdate.

In the modified method the molybdenum oximate destruction and molybdic oxide precipitation are not carried out each time but only with the third precipitation. With the first two precipitations, the molybdenum oximate is dissolved in fuming nitric acid and reprecipitated directly. The oxime precipitate is washed only once per precipitation, and only one ferric hydroxide scavenge is made. The modified method consists of the following steps:

1. Ten mg of molybdenum (VI) are added to the sample in a 40-ml test tube, and the volume is adjusted to 30 ml and the acidity to approximately 1 *M*. Five ml of 2% α-benzoin oxime in ethanol are added, and the mixture stirred and centrifuged. The precipitate is washed with 30 ml of water.
2. The precipitate is dissolved in 3 ml fuming HNO_3; the solution is diluted to 25 ml with water, partially neutralized with 1–2 ml of ammonium hydroxide, and cooled in an ice bath.
3. The molybdenum is reprecipitated by adding 5 ml of the oxime reagent. The mixture is stirred and centrifuged.
4. Steps 2 and 3 are repeated.
5. The precipitate of step 4 is dissolved in 3 ml of fuming nitric acid. Three ml perchloric acid is added, and the solution boiled down (caution!!)‡ until the perchloric acid starts fuming and 30 sec longer. Then the mixture is cooled.
6. Ten ml of water and 1 mg of ferric ion are added; then ammonium or sodium hydroxide is added until the molybdic oxide dissolves and ferric hydroxide has precipitated. The mixture is filtered through any fast filter paper such as Whatman 4 or 41.
7. The molybdenum is then precipitated as lead molybdate in the usual manner.

The chemical yield is 70–75%. A uranium solution containing $\sim 10^{12}$ fissions/ml was analyzed for molybdenum 8 days after bombardment. Three 1-ml and three 0.5-ml aliquots were withdrawn and analyzed using the modified procedure. The lead molybdate precipitates were mounted on brass planchets and counted on the second shelf (0.81 in. from the counter window) through a 13.05 mg/cm² Al absorber using a gas-flow proportional counter. The counting rates were corrected for chemical yield, aliquot, and decay. The standard deviation from the mean was 0.8%.

The activity of the samples was followed for 10 days; each showed a half-life of 66 hr and no apparent contamination.

* E. C. Freiling, L. R. Bunney, N. E. Ballou, *Phys. Rev.* **96**, 102 (1954).

† N. E. Ballou, in National Nuclear Energy Series IV-9, paper 257 (McGraw-Hill Book Co., Inc., New York, 1951).

‡ There is a great deal of frothing when boiling down molybdenum oximate-fuming nitric acid-perchloric acid solution; care must be exercised not to boil the solution right out of the test tube.

TECHNICAL BRIEF

Radiation-resistant, photosensitive plastic. A plastic having a plasticized ploy vinyl chloride base—sensitive to ultraviolet radiation and relatively insensitive to gamma radiation—has been developed by Ferro Chemical Corp. under Signal Corps contract.

The plastic provides a simple, fast means for printing photographic negatives without the usual darkroom and developing chemicals. It is exposed to the negative using a u-v source and is developed in an oven at 320°–350° F in 5 min. The exposure can be made under ordinary room lighting conditions. Pictures are clear, durable, waterproof, and stronger than paper prints.

Limited tests show that 2,000-roentgen Co^{60} irradiation and 1,700-roentgen irradiation with 65-kv X-rays produce only slight darkening on developing. No effect is detected below 100 roentgens.

Image formation depends on heat degradation of polyvinyl chloride, which produces conjugated polyenic structures. These structures, when sufficiently concentrated and of sufficient conjugation length, produce a darkening and discoloration of the film. Certain dyes—e.g., aromatic compounds of the quinone type—modify or intensify the color produced. Certain catalysts—e.g., metal compounds, in which the metal is of the type used in Friedel-Crafts reactions—accelerate the degradation.

Physical properties, such as hardness and tensile strength, have not been tested.

The plastic, called Calimar, is available in experimental quantities.

NEXT MONTH

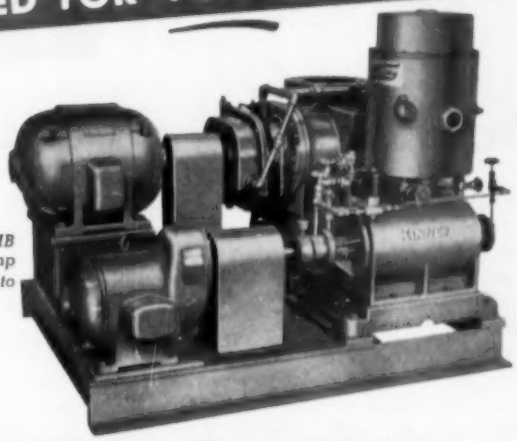
NUCLEONICS

will feature a special report on **"Simulation and Computation in Nuclear Engineering"**

Kinney®

VACUUM

PRESCRIBED FOR YOUR PROJECT



The famous KINNEY KMB Mechanical Booster Pump which develops pressures to .0001 mm Hg.

When you know precisely your Vacuum requirements or when the problem is not so readily defined—KINNEY represents your best chance of resolving the matter correctly, quickly and economically.

With the world's most comprehensive range of High Vacuum Pumps, KINNEY obviously offers a virtual prescription selection. There are single-stage Simplex and Duplex models to develop pressures to 10 microns . . . Compound models for work in the order of 0.2 micron . . . and finally KINNEY Mechanical Booster Pumps that reach ultimate pressures of 0.1 micron.

Beyond this unparalleled array of High Vacuum Pumps, KINNEY offers complete Vacuum Systems . . . Packaged Pumping Units, High Elevation Chambers, Packaged Power Units, Vacuum Furnaces, Evaporators, Ovens and Cathodic Etching Equipment. And finally, a full range of Fractionating and Non-Fractionating Diffusion Pumps, Valves and Baffles, Gauges, Leak Detectors and other Test equipment.

WRITE: Write for full information on KINNEY High Vacuum Pumps, Systems and Components.

KINNEY MFG. DIVISION
THE NEW YORK AIR BRAKE COMPANY
3614D WASHINGTON STREET • BOSTON 30 • MASS.

Kindly send me your latest literature describing new developments in:

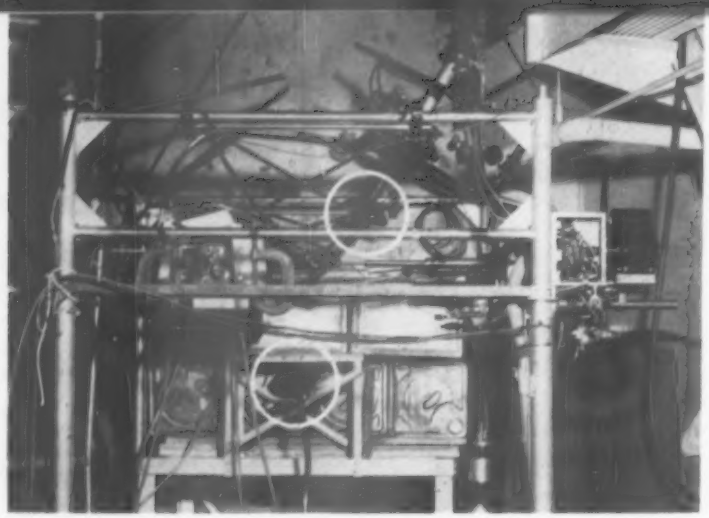
- ☐ KINNEY High Vacuum Pumps
- ☐ KINNEY High Vacuum Systems
- ☐ KINNEY High Vacuum Components

Name_____

Company_____

Address_____

City_____ Zone____ State_____



AFTER INCIDENT Godiva critical assembly shows effects of thermal shock. Note broken steel support rods and pieces of U^{235} left hanging. (shown circled)

Godiva Wrecked at Los Alamos

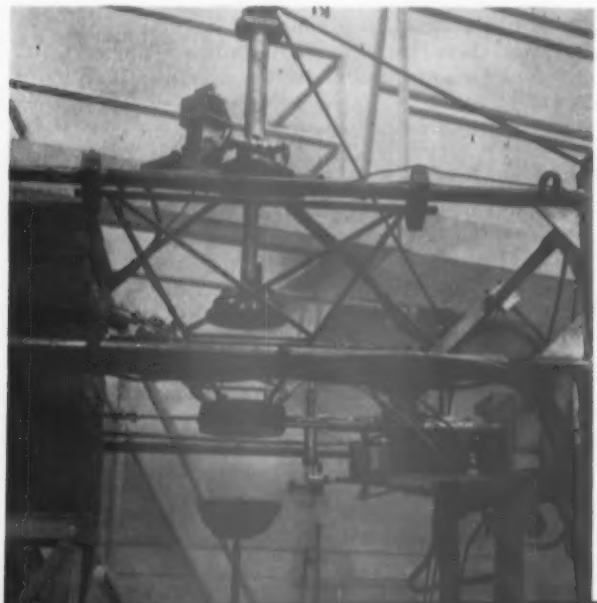
As a result of the motion of an incidental neutron reflector, Godiva,* the Los Alamos critical assembly of bare unreflected U^{235} metal, underwent a second unexpectedly large prompt-critical burst last February 12. This burst ruptured uranium screws that held subunits together, deformed the uranium surfaces, oxidized their surfaces, and broke lighter steel supports. The estimated magnitude of the burst was 1.2×10^{17} fissions, about twice that of an earlier incident (February 3, 1954), and six times the largest expected burst. Because of the quarter-mile distance between Godiva and control-laboratory areas, the incident led to no detectable personnel exposure. Neighboring equipment was not harmed.

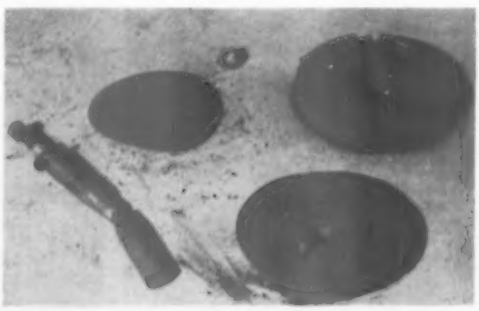
Godiva was being used to irradiate uranium-loaded graphite to determine the behavior of this material after exposure to a sudden wave of neutrons. Apparently the polyethylene-encased graphite shifted closer to the critical assembly than intended. The shift in position caused the polyethylene to reflect neutrons back into the critical assembly, increasing the chain reaction and resulting in the sudden increase in heat that produced the thermal shock in the assembly.

Though Godiva was not originally intended for the purpose, it had become a fast-neutron irradiation facility (the study of its properties was completed several years ago). Because of continuing demand for irradiations, the immediate plan is to replace Godiva by a bare uranium assembly that has been designed specifically for burst production. Some features of the new machine, aimed at increased reliability of operation, are: rigid mounting, inflexible geometry, combination gross-mass-adjustment rod and auxiliary scram, fixed-value reactivity booster for burst generation, a cage to establish minimum spacing of objects to be irradiated, and a remotely-positionable neutron source.

Godiva operations, started in August 1951, were first directed at calibration and neutronics measurements, eventually including a study of prompt bursts. There were some early requests for irradiations, and many more when burst production was demonstrated. Thus, the transition to a radiation facility was gradual. During its lifetime, Godiva produced 1,060 bursts, and 780 "high-level" delayed-critical irradiations, both kinds averaging $\sim 10^{16}$ fissions each.

* Godiva was described by H. C. Paxton, NUCLEONICS **13,** No. 10, 48 (1955); more detail is in R. E. Peterson, G. A. Newby, *Nuclear Science and Engineering* **1,** 112 (1956). We are indebted to Dr. Paxton for this account.





OXIDIZED COMPONENTS of Godiva were knocked from sphere by thermal shock. Bar on left was actually lengthened by instantaneous pressure

BEFORE INCIDENT three sections could be brought together to form bare critical mass in form of $6\frac{3}{4}$-in.-dia sphere

Air-Drying System for EBWR Turbine Seals

By EDWARD L. YOUNG
Nuclear Power Department
Allis-Chalmers Manufacturing Co.
Milwaukee, Wisconsin

An interesting new application of air-drying equipment is found in the Experimental Boiling Water Reactor steam plant now in operation at the Argonne National Laboratory. The EBWR air-drying and moisture-recovery system will prevent the loss of valuable moderator and the escape of radioactivity to the atmosphere. The drying system is automatic and remote-controlled; it should prove useful in other nuclear applications where vapors must be captured.

Necessity for Dry Air

The EBWR differs from other nuclear power cycles in that the heat energy developed in the reactor is carried in the form of high-pressure, high-temperature steam directly to the turbine. The reactor will be moderated for the present with light water, but it is planned to use heavy water at an early date to gain full reactor efficiency. At an estimated $200/gal for heavy water, conservation will be essential.

As in conventional steam-turbine installations, a small amount of air at +6 in. H_2O is allowed to bleed into the system at the turbine seals to prevent leakage outward of steam. This air is later removed from the system by an air ejector. To prevent the dilution of the heavy-water moderator by atmospheric moisture brought in at the seals and to prevent the loss of heavy water contained in the air removed by the air ejector, an air-drying system is included in the EBWR power cycle. Moisture recovery from the air ejector is essential for two reasons: first, to prevent the escape of radioactive elements in the water; and second, to conserve the water.

In a conventional steam generating cycle of the capacity of the EBWR cycle, an inleakage of 50 lb/hr of air would be considered normal. This would occur principally at the turbine glands where a small amount of inleakage is tolerated to seal the steam. Assuming that this air were permitted to enter the system at 75° F and with a relative humidity of 70%, there would be 0.66 lb/hr, or 15.8 lb/day, of water entering the system. If air is permitted to enter the system, is cooled to ~110° F, and then vented to the atmosphere, as would be the case in a conventional system, the loss of heavy water from the EBWR system would be ~71 lb/day. This would amount to a fixed operating cost of about $2,000/day, which approaches the value of the power produced.

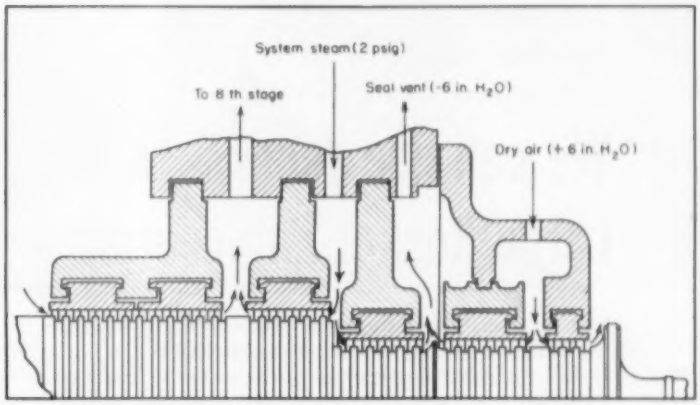


FIG. 1. Seal for high-pressure end of EBWR turbine shaft

Turbine Seals

The type of seal developed for the 5,000-kw turbine is illustrated in Fig. 1. The seal is standard except for the addition of a third chamber to prevent the leakage inward of atmospheric air. It consists of three chambers, each separated by a series of spring-backed baffle rings which form a series of radial restrictions between shaft and casing.

Dry air at a pressure of +6 in. water gage is applied to the first

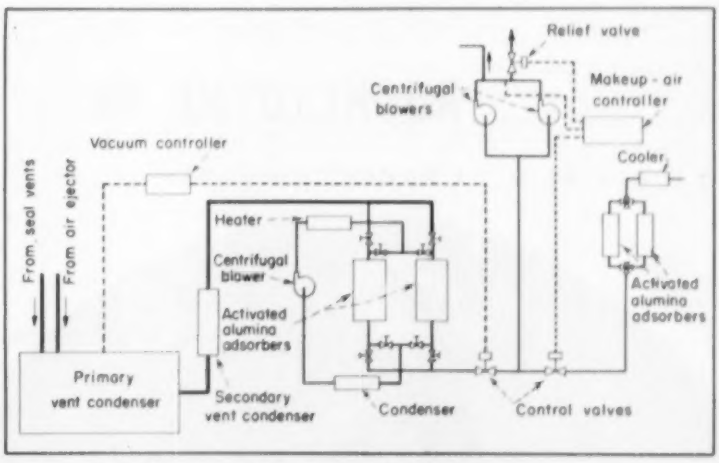
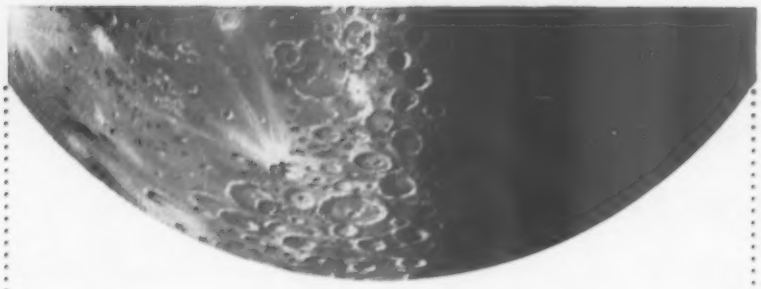


FIG. 2. Schematic diagram of air-drying and moisture-recovery system



To that rare breed of men who can

"see" the shape of things to come:

We can use your ideas in Large Rocket Engineering

We have a small but heavyweight group here at Rocketdyne known as the Preliminary Analysis & Design Section.

These are our idea men. It's their job to see the Big Picture... to approach outer-space projects without earthbound prejudice ...to anticipate problems and sense the likeliest ways to solve them. They are qualified experts in a broad range of fields. Some have extraordinary imaginations; others are brilliant analysts; but all share the ability to hit the highlights without becoming enmeshed in the details. In short, they are scientific skirmishers who scout each new challenge—then summon research and development specialists to meet it.

If this sounds like *your* kind of group, you may be the very man we're seeking for one of the several jobs now available. We can't describe them in detail here, but they include *Controls, New Concepts* (nuclear and ion applications), *Preliminary Design, Fluid Mechanics, Heat Transfer, Engine & Missile Systems,* and *Military Operations Analysis.*

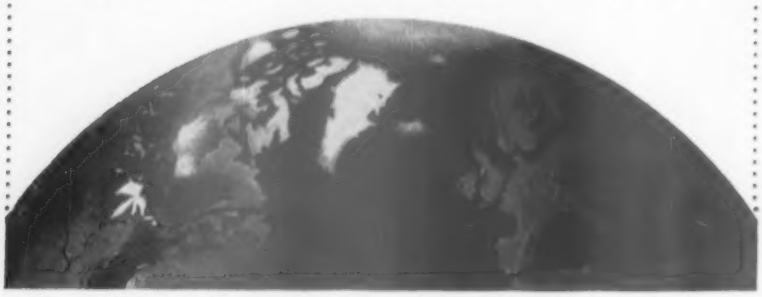
We can use men with advanced degrees and solid experience in control systems and power-plant design. If you are a young engineer or physicist with an M.S. or Ph.D. and an analytical turn of mind, we can offer on-the-job training in many pioneering fields where experience is practically nonexistent.

Please tell us about yourself—what you've done... what you'd like to do. Write: A. W. Jamieson, Rocketdyne Engineering Personnel Dept. C-4, 6633 Canoga Ave., Canoga Park, California.

ROCKETDYNE

A DIVISION OF NORTH AMERICAN AVIATION, INC.

BUILDERS OF POWER FOR OUTER SPACE



chamber. The second chamber is maintained at −6 in. water gage vacuum. The third chamber is maintained at a pressure of ½–2 psig with steam. As a result, dry air will leak outward from the seal at a flow sufficient to prevent leakage inward of atmospheric air. This same sealing arrangement, with slight modifications, is applied to the reactor feed pumps, turbine horizontal joint flange, and other points where leakage may occur.

About one-half of the air supplied to the seals is recirculated air from the vacuum side of the seals which has been dried to a dewpoint of −40° F. Makeup air is taken from the atmosphere and dried to the same dewpoint.

Air-Drying System

The system was designed to be located within the gastight enclosure that surrounds the entire reactor and generating equipment. Figure 2 shows how the system works. The air-and-steam mixture from the seals, as well as from the condenser air ejector, enters the air-drying system at the primary vent condenser where ~90% of the vapor is condensed from the mixture. The air then passes to the refrigerated secondary vent condenser where more of the vapor is condensed. Air leaving the secondary vent condenser is at a controlled temperature of 40° F and flows to the activated-alumina adsorbers where it is dried to a final moisture content of less than 0.5 grains/lb of dry air.

Makeup air from the atmosphere enters the system through a refrigerated cooler that lowers the temperature of the air to ~40° F. From here the air flows through a second set of activated-alumina adsorbers where the moisture content of the air is reduced as before.

To maintain a flow throughout the entire system, totally enclosed centrifugal blowers are provided.

The two sets of activated-alumina adsorbers consist of two units each to permit one unit to operate while the other is being reactivated. Reactivation in the primary moisture-recovery section is effected by a centrifugal blower, an electric heater and a water-cooled condenser, designed to dry the alumina in ~8 hr. Moisture removed by the condenser is returned to the system.

In the makeup-air section, the heaters are built into the adsorbers. Air forced through the unit under

About the

NUCLEAR PRODUCTS DIVISION OF SUPERIOR TUBE

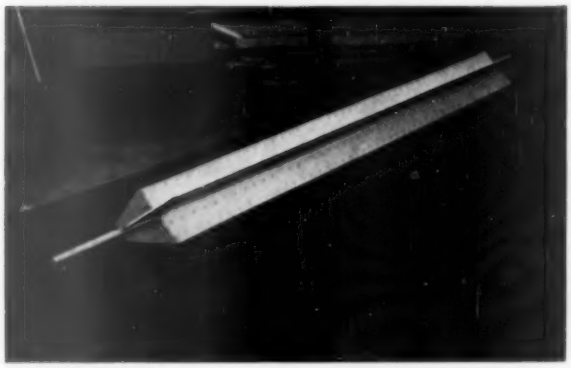
For design and construction of intricate reactor components of special types

PEOPLE

This division offers the atomic industry the teamwork of a wide variety of highly skilled personnel, including mechanical, metallurgical and welding engineers, fully qualified to assist in developing Classified and commercial projects. They are supported by expert inspectors and quality control people who insure close adherence to all specifications.

TOOLS

Equipment includes a modern vacuum welding chamber; a variety of hydraulic presses; facilities for atmosphere, vacuum furnace and salt-bath heat treating; swaging machines; high pressure-and-temperature autoclaves for corrosion testing; pickling and rinsing baths; milling, turning, shaping and planing machines; and modern final inspection equipment.



KNOW-HOW

Among the many products being turned out by this division are specially shaped control rod channels, assembly channels, and control rods; also reactor components produced from sheet, bar and plate in squares, hexagons, rectangles or rhombuses, all produced to very close tolerances. The Nuclear Products Division is currently serving many of the key manufacturers in the atomic energy field.

SERVICES

These include help in the design of reactor components; design and construction of intricate tools and fixtures to fabricate reactor components; development of manufacturing facilities after the prototype has been fabricated. Many materials are utilized, including the reactive metals—titanium, zirconium and their alloys. We also supply tubing for many atomic applications.

For information on our Nuclear Products Division or tubing for atomic power, write Superior Tube Company, 2027 Germantown Ave., Norristown, Pa

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅛ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331

reactivation is vented to the atmosphere. Each unit requires a 4 hr cooling period making a total reactivating cycle of 8 hr.

Control

During both startup and operation of the system, all vacuum and pressure functions are assumed by two controllers and three air-operated control valves. The positive pressure at the discharge of the system is maintained by a control valve at the discharge of the makeup-air adsorber and a relief valve at the system discharge. These two valves operate on a split range and are actuated by the makeup-air controller. The makeup-air controller measures the discharge pressure and adjusts the flow of air into or out of the system at a rate sufficient to maintain the preset pressure.

Vacuum at the inlet to the system is maintained by a control valve at the discharge of the moisture-recovery adsorber. A vacuum controller measures suction at the primary vent condenser and adjusts air flow through the moisture-recovery system so that the preset vacuum is maintained there. Both the makeup-air controller and the vacuum controller are of the proportional type with automatic resets.

All pressures and vacuums are maintained automatically by the system of valves and controllers described. Recycling of the alumina adsorbers is automatically controlled by a system of timers and relays, and needs no attention from the operator. Temperature of the air leaving the coolers is automatically maintained.

These automatically controlled components are provided with alarm signals in the control room. As a further safeguard against possible system failure, a spare blower and refrigerant compressor are provided, together with automatic controls for their operation in the event that the preset limits of pressure and temperature are not maintained.

Capacity

The air-drying and fluid-recovery system has a capacity of 150 lb/hr of air from the seal vents and can supply 150 lb/hr of dry makeup air. It was also designed to handle an additional 100 lb/hr of air and vapor from the air ejectors during system evacuation. These flow rates include a large factor of safety so that future additional components can be served without changes in the air-drying system.

Amplification

The billion-fold amplification of the image left by light in silver halides, a problem which has interested many scientists, is only one of current problems being attacked by Technical Operations, Incorporated. Your association with Technical Operations' scientific staff can mean comparable amplification.

for your career as a

Physicist or Mathematician

It can also mean:

- simple, sensible salary policies
- management by scientists
- long-range security
- unusual joint company-employee savings plan

Senior scientists will find limitless opportunity in experimental research and development—in chemistry, physics, nucleonics and electronics. Challenging positions are available in theoretical work in physics, operations research, and other fields.

*Dr. Bernard Manning, of Technical Operations' Chemistry Group.

address: Robert L. Koller

TECHNICAL OPERATIONS
INCORPORATED
Research and Development
for business, industry and government
6 Schouler Court
Arlington 74, Massachusetts

FOR SCINTILLATION & PROPORTIONAL COUNTING
NON-OVERLOADING LINEAR AMPLIFIERS

Models 108 & 108P
Gain 40,000 continuously variable
Rise 0.2 microsec
Accept + and − pulses

TREMENDOUS DYNAMIC RANGE Exceeds 1,000,000 (0.1 mv to 100v)
Based on improved Chase-Higinbotham design. Excellent linearity for small pulses in the presence of tremendous overloads that paralyze other amplifiers.
PULSE HEIGHT SELECTOR (Supplied only on Model 108P)—Precision trigger-type.

PRECISION HIGH VOLTAGE SUPPLIES

Model 515 (Positive and Negative)

- 500–1500 volts, 1 m.a. (2 m.a. to 1KV)
- Continuously variable
- Polarity switch makes this highly regulated supply equivalent to two separate precision instruments
- Drift less than .01% over several hours; less than .02% per day. Regulation .0002% per % change in line voltage for line voltages between 70 and 140
- Precision voltage divider (0.1% resistors) for precise reading of output voltage
- 4½" panel meter. Dual teflon connectors

Model 108	Amplifier	$545.00
Model 108P	Amplifier (includes pulse-height selector)	$595.00
Model 112	Amplifier (gain of 1000)	$350.00
Model 401	Mercury Pulse Generator	$125.00
Model 515	HV Supply (500-1500 volts)	$385.00
Model 540	HV Supply (1000-4000 volts)	$535.00
Model 412	Sliding Pulser	$450.00

(prices FOB Silver Spring)

RADIATION INSTRUMENT CO.
P.O. BOX 733 SILVER SPRING, MARYLAND

Gadolinium, Gadolinium chlori
Galactonic acid lactone, Gala
loride, G ntaacetat
ethanola allic aci
Gallium c lium nit
Gallocyanin, Gallophenine, Ga
hydrol e, Gel
acid, G e, Ge
ethanol isic a
acetate, Germyl bromide, Ger
Germanium metal, Germanium mo
te ra
te ap
Gi r
Gitoxigenin, Gitoxin, Gliadin
Glucoascorbi d, Glucochlo
acid d, Gluc acid, Glucon
Glucosaminic , Glucose al
Glucose-o-carboxyanilide, Glu
Glucose dibenzylmercaptal, Gl
mercap se, m thylme
ethylxa ose oxamin
pentaacetate, Glucose Sodium
Glucose thioureide, Glucose u
Glucosides, Glucos do-5-pyrid
trimethylammonium Gl
curonidase, Glucu e,
tamic acid, Glut ut
dioxime, Glutara ri
anhydride, Glut hyd
reduced, Glutat ize
cami Glyceric cero
de linium olin
c ric ac osar

OVER 20,000 CHEMICALS IN STOCK!

Write for Our New 138-Page Catalog!

DELTA CHEMICAL WORKS, Inc.
23 West 60th St. New York 23, N. Y.
Telephone: Plaza 7-6317

Diphenyl as a Thermodynamic Fluid

By D. C. PURDY
Reactor Development Department
Engineering Division
Chrysler Corp.
Ann Arbor, Michigan

Recent interest in the use of diphenyl as a reactor coolant has served to make its properties familiar. This familiarity often leads to suggestions that diphenyl might find additional uses in nuclear power plants. This article concerns itself with one such suggestion: using diphenyl as the working fluid in a heat engine.

As it turns out, this is not a new idea. In the 1930's, two articles on this subject appeared in the British literature (*1*, *2*). Also, for a time, the Dow Chemical Co. attempted to promote the use of diphenyl's near kin, Dowtherm, in binary heat-engine cycles. None of these suggestions bore fruit, apparently because the same goal—increased thermal efficiency—was achieved more simply through the use of higher steam temperatures and pressures.

Potential Applications

This article presents the results of a new investigation into the use of diphenyl as the working fluid in a heat engine. This information should prove to be of interest at this time for two basic reasons. First, experience with the Organic Moderated Reactor Experiment may lead to consideration of a boiling-diphenyl reactor, similar in principle to the boiling-water reactors. Second, diphenyl may prove to be advantageous as an intermediate fluid for liquid-metal-cooled reactors. Diphenyl will not react violently with liquid metals such as bismuth, sodium, or NaK, nor does it react with water or steam.

Limitations

Diphenyl, of course, has certain limitations as a thermodynamic fluid. Thermal decomposition will limit the temperature of diphenyl cycles to somewhere in the neighborhood of 750–800° F. Radiation damage may be more of a problem where a thermodynamic cycle is involved than where diphenyl is used simply as a coolant because of changes in vapor pressure. In addition, diphenyl is inflammable.

Thermodynamically, diphenyl resembles steam in that both the liquid and vapor phases are encountered in the cycle, and in that most commonly pressures used are below the critical pressure. A substantial portion of the heat absorbed in both steam and diphenyl cycles is absorbed during boiling.

Diphenyl Cycle

A typical diphenyl cycle is shown superimposed on the diphenyl saturation curve in Fig. 1. The peculiar slope of the curve separating the superheated region from the saturated region should be noted. Because of this slope, diphenyl becomes more superheated as it expands through a turbine. Also, at any reasonable exhaust pressure, the diphenyl temperature at the turbine exhaust is much higher than that in the condenser. Thus, regeneration similar to that encountered in gas turbine cycles can be used.

The efficiency and turbine-exhaust volume flow were calculated for saturated diphenyl cycles with various initial temperatures. Three efficiency curves were derived (Fig. 2): one for zero regeneration, one for 85% regeneration, and one for perfect regeneration. A turbine efficiency of

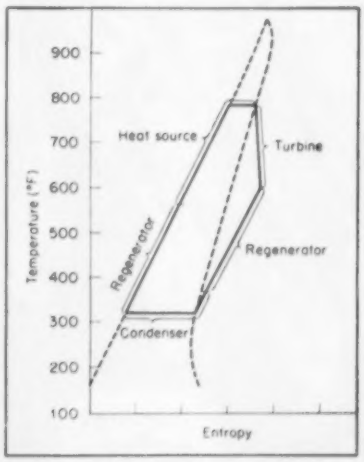


FIG. 1. Typical diphenyl cycle (solid) superimposed on diphenyl saturation curve (dotted)

PROMPT DELIVERY
A GRAM OR A CARLOAD

thorium
OXIDE
(SEVERAL GRADES)
FLUORIDE
NITRATE
AND OTHER SALTS

neutron absorbers
GADOLINIUM
SAMARIUM
EUROPIUM
AND OTHER SEPARATED RARE EARTHS

WRITE FOR TECHNICAL DATA

World's largest producer of rare earth and thorium chemicals for commercial atomic energy use and industrial applications

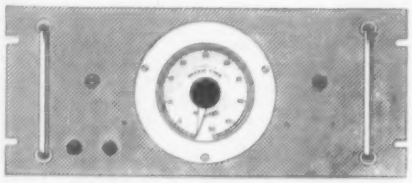
LINDSAY CHEMICAL COMPANY
272 ANN STREET, WEST CHICAGO, ILL.

AUTOMATIC CONTROL OF TIME INTERVAL

with the NEW I.D.L.

AUTOMATIC TIMER UNIT TYPE No. 590

It controls the counting period of the Scaler, Type No. 500 and Pre-Scaler, Type No. 501 with an accuracy of better than 0.25% maximum scale reading. Standard range 0-100 seconds but available in 10 other ranges up to 0-24 hours.



Full details from:

ISOTOPE DEVELOPMENTS LIMITED

BEENHAM GRANGE, ALDERMASTON WHARF, Nr. READING, BERKS. TELEPHONE: WOOLHAMPTON 451/3

LONDON OFFICE: 120 MOORGATE, LONDON, E.C.2. TELEPHONE: METROPOLITAN 9641

REACH, GRASP, LIFT anywhere in hot cell

The General Mills Mechanical Arm increases many times your strength and dexterity, enables you to perform heavy-duty, delicate or intricate tasks with equal ease—remotely.

- Lift and carry 750-lb. loads
- Handle delicate equipment
- Assemble complex machines

Fully coordinated, pistol-grip controls are easily mastered. Adaptable to telescopic or television viewing; easily mounted on crane or vehicle.

Booklet gives details. Send for copy today.

MECHANICAL DIVISION

1620 Central Avenue • Minneapolis 13, Minn.

General Mills

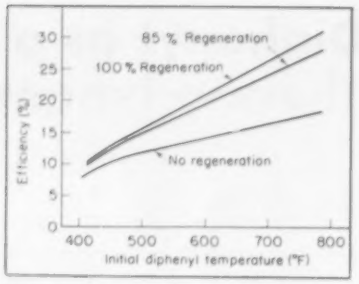


FIG. 2. Diphenyl cycle efficiency as a function of initial temperature

85% was assumed, and pressures drops throughout the system were ignored. The cycle efficiencies shown can be corrected for other turbine efficiencies. Correction for other regenerator effectiveness can be made by interpolation.

The thermodynmic properties of diphenyl used in the calculations, except for specific volume, were from the literature (*2*, *3*). Specific volume in the superheated region was calculated using the perfect-gas laws. This procedure introduces a possible 30% error in the volume-flow calculation.

Assumptions

The turbine efficiency was assumed to be 85% because a diphenyl turbine should be somewhat more efficient than a steam turbine since its volume flow is quite high and there is no moisture problem to contend with in the last few stages. On the other hand, its efficiency may not be so good as a gas turbine's, because the volume flow rate varies over a wide range from the first to last stages.

The regenerator effectiveness was also assumed to be 85%. This figure was based on calculations which showed that 85% regeneration resulted in a regenerator of reasonable size. Gas-turbine experience indicates that this result should be expected. Heat transfer in a diphenyl regenerator should be better than that in an air regenerator since the fluid in the cold side is a liquid. The effect of pressure drops and feed-pump work was ignored in all these calculations, for convenience, as being negligible.

An assumption of especial importance in these cycle studies is one of the choice of condenser vacuum since this choice sets the lower temperature limit for the cycle. One of the major limitations of diphenyl is its low vapor pressure, which requires extraordinarily low condenser pressure to permit reasonable condenser tem-

perature. In this study, it was found that 1 psia was about as low as one could reasonably expect to use. At this pressure, the turbine-exhaust volume flow is about the same as that for a steam turbine (see Fig. 3). Using appreciably lower condenser pressure would require a larger turbine.

Binary Cycle

As an extension of the work described above, binary cycles using diphenyl as the high-temperature fluid, and steam as the low-temperature fluid, were investigated. It was hoped that this approach would lead to increased thermal efficiency. In this type of cycle, the diphenyl loop can be regarded as an intermediate loop with one added component—the turbine. By using this arrangement, a thermodynamic advantage can be gained from the existence of the intermediate loop.

The diphenyl portions of the binary cycles are similar to the cycles with 85% regeneration, except that the exhaust pressure has been raised to 5 psia. The steam cycle uses saturated steam at 200 psia, with a condenser vacuum of 2 in. of mercury, absolute. An alternate arrangement, eliminating regeneration in the diphenyl loop and using superheated steam, was rejected because it would have involved a gas to gas heat exchanger.

A series of calculations using an initial diphenyl pressure of 200 psia showed that varying diphenyl condenser pressure and steam boiler

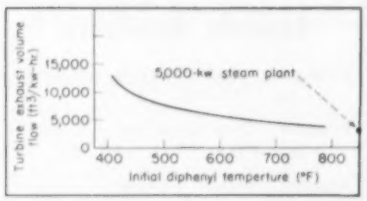


FIG. 3. Diphenyl cycle volume flow as a function of initial temperature

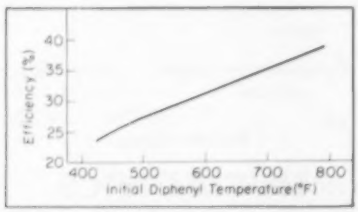


FIG. 4. Efficiency of diphenyl-steam binary cycles

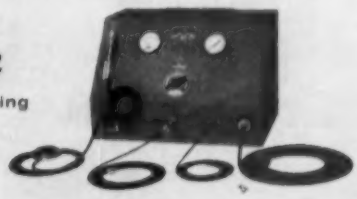
for Super-Fine Cutting
of Hard, Brittle Materials...
the S.S.White
Industrial Airbrasive® Unit

Many delicate industrial cutting and abrading operations – once considered impractical or downright impossible – are now easily accomplished with our Industrial Airbrasive Unit. Developed from the Airdent® equipment made by S. S. WHITE for the dental profession, the unit gas-propels a concentrated stream of abrasive particles at high speed for a fast, cool, shockless cutting action.

The unit can be used in wire-stripping . . . calibrating . . . to remove surface deposits . . . etch glass . . . cut germanium and other crystalline forms . . . or to etch, drill and light-debur hard, brittle materials.

Every day, many different industries find new uses for the Airbrasive Unit. Perhaps it can make your own manufacturing process easier, less expensive! To see what the Airbrasive Unit will do on your product, send us sample parts and details. For further information, just write to

S.S.White
First Name in Airbrasive Cutting



S. S. White Industrial Division, Dept. 15A, 10 East 40th Street, New York 16, N. Y.
Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

pressure did not influence the cycle efficiency (see Fig. 4) or the steam volume flow appreciably. Accordingly, all subsequent calculations involving different initial diphenyl pressures were performed with a constant steam pressure of 200 psia. A steam-turbine efficiency of 76% was chosen. As in the diphenyl cycle, the effect of pressure drop and feed-pump power was ignored.

Conclusions

Diphenyl appears to permit thermodynamic cycles with reasonable thermal efficiency and volume flow. With the condenser pressure assumed in this study, steam turbines using the same initial temperature tend to have better efficiency. If lower condenser pressures prove feasible, the diphenyl turbine may equal the efficiency of the steam turbine. If it fits in the over-all plant better, diphenyl might be substituted for steam.

Use of a diphenyl-steam binary cycle will yield excellent thermodynamic efficiency. It may be a logical choice where the reactor plant requires the use of an intermediate loop.

BIBLIOGRAPHY

1. W. S. Findlay, *The Power Engineer* **29**, 89 (1934)
2. S. J. Ellis, *J. Inst. Civil Engrs. (London)* **10**, 227 (1938)
3. W. K. Anderson. Engineering Properties of Diphenyl, ANL 5121 (1953)
4. J. K. Salisbury, "Steam Turbines and Their Cycles" (John Wiley & Sons, Inc., New York, 1950)
5. J. H. Keenan, F. G. Keyes, "Thermodynamic Properties of Steam" (John Wiley & Sons, Inc., New York, 1936)

careers in peaceful applications of atomic energy

ENGINEERS

SPECIALIST IN STRESS ANALYSIS AND HEAT TRANSFER

Education: B.S., M.S. or Ph.D. in Engineering

Experience: At least 2 to 4 years applicable experience required.

Duties: Stress and Heat Transfer analysis of nuclear reactors and reactor components.

SPECIALIST IN SYSTEMS ANALYSIS

Education: B.S., M.S. or Ph.D. in Electrical Engineering.

Experience: 0 to 5 years experience in control and systems analysis.

Duties: Perform and direct analysis of reactor and power plant control systems, reactor and power plant dynamics.

Write: Answer will be prompt and confidential.

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

Mr. G. W. Newton, Personnel Office, Dept. C-4,
21600 Vanowen Street, Canoga Park, California
(In the Suburban San Fernando Valley, Los Angeles)

Reprints Available

Applying Radiation in Industry (May '56)—$1.25

Russian Thermonuclear Experiments (June '56)—$0.10

Reactor report (Aug. '56)—single copies free of charge

Research Reactors for Export (Nov. '56)—$0.75

Why Britain Claims World Lead in Nuclear Power (Dec. '56)—$0.75

Pyrophoricity report (Dec. '56)—$0.25

Reprint Dept.

NUCLEONICS

330 W. 42nd St., New York, N. Y.

Stainless steel reactor vessel was built by ALCO, along with many components, for APPR *(inset cutaway)*. ALCO also served as prime contractor on plant.

PROVED NUCLEAR COMPONENTS FROM ALCO

ALCO components for nuclear reactors are result of long thermal and nuclear experience; proved in operation of various atomic projects

ALCO has built heat exchangers for the EBR, S1W, S2W, PWR and SRE systems, as well as most components, including control-rod drives and piping, for the APPR-1. ALCO components were also installed in the first two Hanford reactors.

ALCO's extensive experience is one explanation for the success of its components in these programs. For many years it has been a leading supplier of equipment to the power and process industries.

ALCO's continuing research is another explanation. To keep ahead, ALCO operates its own criticality facility – the first privately owned installation in the country – and complete welding, heat-transfer and mechanical laboratories. An electronic computing center is maintained at ALCO to provide fast, accurate answers.

ALCO can help you in your nuclear project. Consult your ALCO sales office, or write Thermal Products Division, Dept. NC-1, P.O. Box 1065, Schenectady 1, N.Y.

ALCO Nuclear Components

reactors
reactor vessels
control-rod drive mechanisms
pressurizers
steam generators
core support structures
core removal and handling equipment
regenerative and non-regenerative exchangers
liquid metal exchangers
decay exchangers
special heat-transfer equipment

ALCO

ALCO PRODUCTS, INC.

NEW YORK

Sales Offices in Principal Cities

Locomotives · Diesel Engines · Nuclear Reactors · Heat Exchangers · Springs · Steel Pipe · Forgings · Weldments · Oil-Field Equipment

M1238-1818 — *Range 18" x 18", working distance 9" to infinity. Reads to 0.001" up to 24" working distance. Protractor ocular reads to 3 minutes of arc. Image is erect.*

Cut inspection time in half

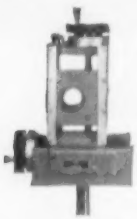
with new Gaertner Coordinate Cathetometers

These convenient, reliable optical instruments permit making precise coordinate measurements in a vertical plane. The two dimensions are measured with one setting, object does not have to be rotated. Inspection time is cut in half and resetting errors eliminated.

Versatile Gaertner Coordinate Cathetometers are ideally suited for precision measurements on large objects; also objects or points in recessed, remote, or inaccessible locations. Applications include measuring jet engine sections, complicated castings, printed circuits, bolt holes and bosses on large piece parts, traces on cathode ray tubes, etc.

Because these are optical rather than mechanical measuring instruments, you make non-destructive measurements without contact, distortion, or concern about pressure being applied to the object when making a setting. Instruments available in English or Metric system.

M1236-46— Horizontal range 6", vertical range 4". Reads to 0.0001", working distance 5" to infinity.



M1236-22— Range 2" x 2", reads to 0.0001". Working distance 5" to infinity. Shown with 19 mm mounting rod, and without telemicroscope. Instrument permits precise coordinate movement of other objects such as photo cells, probes, etc., in place of telemicroscope.

Write for Bulletin 188-53

The Gaertner Scientific Corporation

1257 Wrightwood Ave., Chicago 14, Ill.
Telephone: BUckingham 1-5335

APPLIED RADIATION

ASTM to Evaluate Radiation Testing

Radiation doses are currently expressed in roentgens, reps, ergs/gm, rads, watt-hr/gm, gammas or particles/cm² and various combinations of these and other units. The confusion created by such diversity is part of the subject matter to which a subcommittee of the American Society for Testing Materials is addressing itself. The group is a joint subcommittee of Committee D-9 on insulating materials and Committee D-20 on plastics and it will attempt to standardize radiation tests and descriptions of them. D. S. Ballantine of Brookhaven National Laboratory is chairman of the subcommittee.

The subcommittee has divided its interests into five categories: nomenclature and definitions, dosimetry, correlation of various sources of radiation, effects of total dose and dose rate, and post-irradiation effects. A recent meeting at Roanoke, Virginia, concerned itself largely with dosimetry and made plans for future attempts to evaluate methods of dosimetry and compare their appropriateness for different types of problems.

It is the suggestion of the subcommittee that radiation doses be expressed in ergs/gm—ergs of energy absorbed per gram of sample—at least until the matter has been considered further. Meanwhile the nomenclature section will be considering the advantages of rads, megarads, and the like. The main advantages of these units are current acceptance and ease of expression.

People who are interested in the work and those who have contributions to make to the program are invited to contact the chairman.

AEC Evaluates Its Isotope Program

Up to the end of 1956 3,663 United States organizations and individuals had received licenses to have and use byproduct radioisotopes. This is one of several figures presented to indicate the size of the radioisotope program in a recent report prepared by the Atomic Energy Commission for hearings of the Joint Congressional Committee on Atomic Energy.

The potential market for thickness and density gages is only 10% saturated according to the report. Currently there are 3,375 licensed gages. Another unsaturated application is the use of low-level tracers in process control. The report points out that this use is just emerging from the experimental stage.

Radiography is an important application with about 500 organizations using isotopes for this purpose. It is estimated that the cost of isotope radiography is $\frac{1}{5}$–$\frac{1}{10}$ of the cost of X-radiography. This and other cost figures of the report are from a spot check based on interviews with industrial users of radioisotopes.

The medical profession leads all other groups in number of licensed users. Further proof of the importance of medical applications is in the estimate that 800,000 persons are treated with radioisotopes each year for diagnosis, therapy, or both.

An attempt is made to estimate the future need for Co^{60} and Cs^{137} sources. Conversion of all conventional therapeutic X-ray machines to Co^{60} units is envisioned. This would require $\sim 2 \times 10^6$ curies in 2,000 sources in 5 years. The world's Co^{60} requirement in 1966 is estimated as 4,000 sources at an average of 1,000 curies each. Cs^{137} is described as being almost as good as Co^{60} therapeutically and having advantages in ready availability and long half-life.

Private industry is taking a more active part in the radioisotope business than formerly. Nearly 100 private firms are engaged in processing radioisotopes, and there is evidence that private isotope production is imminent.

The following needs for future instrument development are listed at the end of the report: (1) volume production of inexpensive counters for medical purposes, (2) small sensing elements no larger than a pencil eraser for brain probes, (3) low-level industrial counting apparatus for counting rates at background level or below, (4) thin-walled low-cost counters for high-school and college teaching, and (5) counter kits for assembly by students.

The report describes the AEC's efforts directed toward encouragement of industrial utilization of radioisotopes. It points out that regulations have been simplified, general-license quantities have been increased, and manufacturers have been allowed to distribute several products containing radioisotopes without specific licensing of customers.

Gamma Facility for Use at High Temperatures

By E. L. COLICHMAN, P. J. MALLON, and A. A. JARRETT
Atomics International
North American Aviation, Inc.
Canoga Park, California

A laboratory irradiation facility has been designed and built with 2,000 curies of cobalt-60 in a 3-ton movable dome. It is for laboratory irradiation of chemical samples at temperatures up to 450° C. Relatively large volumes can be irradiated with very uniform dose-rate distributions. Radiation levels are reproducibly adjustable from 10^4 to 2.5×10^6 r/hr. Since the average external radiation level is less than 0.1 mr/hr, the facility can be used in a laboratory containing radiation-measuring equipment and people.

Design

The design goals for the irradiation facility were as follows:

1. Reproducible and variable radiation rates at high intensities.
2. Uniform dose rate in large samples.
3. Irradiations below room temperature and up to 450° C.
4. Two irradiation wells to permit setting up an experiment while irradiating in the other well.
5. Low external radiation to permit continuous access during operations and use in a laboratory with radiation-measuring equipment.
6. Access conduits into irradiation wells for use of external electrical or mechanical equipment.
7. Disassembly for movement from one laboratory to another.
8. Shipping casket that is part of irradiation assembly.

An average radiation intensity of 0.1 mr/hr at the surface was ensured by 13 in. of lead in all directions. Steps and barriers at shielding junctions minimize scattered radiation. The facility, shown in Fig. 1, consists of ~10 tons of lead sheathed in a mild-steel casing of ¼-in. plate. All cavity liners are of ⅛-in. stainless steel. Figure 2 shows the geometry of the source and an irradiation volume.

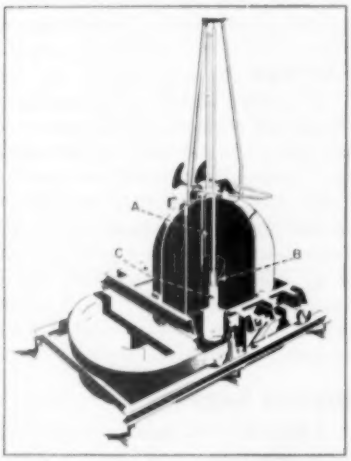


FIG. 1. Movable dome containing source can be moved over either of two irradiation wells. Plug A is for loading source. Wires through channels B can be used to insert shipping plug. C is movable shield that extends into wells to prevent streaming between dome and base

Shielding Dome

The shielding dome is 30 in. in diameter and 28 in. high, and it weighs 6,000 lb. It serves as a shipping casket and as a permanent housing for the gamma source. The upper plug permits easy initial loading of the source.

For shipping purposes a lead plug is installed in the source cavity and a plate is screwed to the bottom of the dome. The plug can be removed and installed in the laboratory by means of wires that reach it through tubes from the top of the casket. During this operation, the assembly is used as a shielded enclosure.

A movable inner shield prevents gamma-ray streaming through the space between the dome and the base. Whenever the source is not completely withdrawn into the dome, this shield is extended into one of the irradiation volumes. It is counterbalanced in such a way that approximately 20 in.-lb holds it in either up or down position. The total movement of the inner shield is only about 1¼ in.

Source

The source container is made up of eight stainless-steel tubes 4½ in. long (Fig. 3). The source consists of forty 50-curie cylinders of cobalt 1 cm high and 1 cm in diameter. A screw plug at the top and a cap at the bottom of each tube retain the cobalt. Cylinders of quartz are used as alternate spacers between cobalt disks to increase the volume available for uniform irradiation. On the top of the source assembly is a boss to which the control shaft is screwed and pinned. An expansion shaft is screwed to the control shaft, and a counterweight is added for operating ease. A meter stick and an indicator on the rod give the position of the source.

Base

The base is made up in two assemblies, each of which has a test hole. When these bases are bolted together, the crack between the two is leaded and no appreciable rise in external radiation is observed even when the casket is located directly over the crack. A step at the top outside edge of the base allows the addition of a "scatter fence" 4 in. thick and 6 in. high. A channel with a 45-deg angle in the middle to prevent streaming is used to introduce thermocouple and power leads into each test hole. These

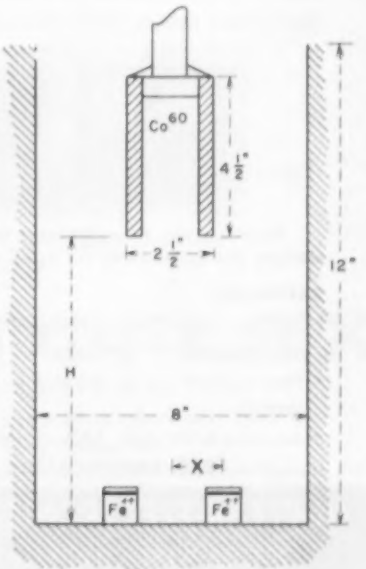


FIG. 2. Geometry of source and well showing arrangement used to measure dose rates

NEW nu-tronic SUPER-SERIES

SCALER AND RATEMETER

For every application . . .

never becomes obsolete!

New unitized construction assures complete adaptability for every application—by eliminating the need to duplicate facilities this modern engineering concept of plug-in units means additional equipment economies!

Input unit available as plug-in G.M. amplifier or plug-in linear amplifier.

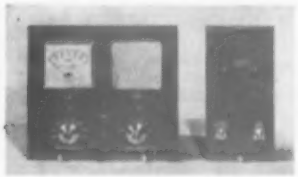
PLUG-IN DECADE SCALER AND TIMER UNIT:

- Choice of decade counting group: (a) one megacycle decade and two 100 KC decades (b) three 100 KC decades
- Built-in timer is adjustable for pre-set time from two seconds to one hour in one second increments
- High speed register allows a counting rate up to 25,000 counts per second through scaler
- Scaling ratio selector allows register to be actuated every 10th, 100th, or 1000th pulse

Power supply is an integral part of the common chassis—both high and low voltage is electronically regulated. High voltage is continuously variable from 500 volts to 2500 volts.

Plug-in power control and meter panel

Plug-in linear amplifier and single channel analyzer



UNITIZED PLUG-IN UNITS

From a scaler to a ratemeter in seconds . . . units are quickly interchanged just by loosening the thumb screws on the front panels!

RATEMETER:

- Eight full scale ranges: 600,000, 300,000, 60,000, 30,000, 6,000, 3,000, 600, and 300 counts per minute.
- Time constant can be selected as follows: 0.5, 1.0, 1.5, 5.0, 10, and 15 seconds
- Accuracy better than ±5% of meter reading

FREE ***SPECIFICATION SHEETS UPON REQUEST!***

NUCLEAR-ELECTRONICS CORP.
2632-36 WEST CUMBERLAND ST.
PHILADELPHIA 32, PENNA.
SAgamore 2-2662

nu-tronic PRODUCTS

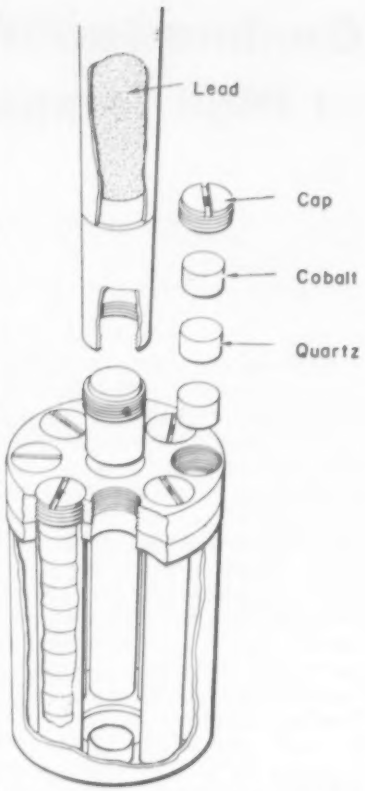


FIG. 3. Source holder has Co^{60} cylinders and quartz spacers in 8 channels around central volume that can be used for irradiations

channels are ½ in. deep and 1 in. wide and run parallel to the upper surface of the base. There are similar channels down one side and across the bottom to the center of each hole.

Carriage

A carriage bolted to the shielding dome and rolling on steel casters on one flat track and one V track carries the dome with a clearance between dome and base of 0.15 in. A pin in the carriage and holes in the flat track locate the dome over either test hole. The dome is easily moved between holes by a crank-driven pinion on the carriage and a rack mounted on the base.

Interlock System

A three-way fail-safe electrical interlock system prevents lowering source or inner shield until the dome has been located over a test hole and indexed in place with the carriage indexing pin. This releases the inner-shield lock. When the inner shield has been completely lowered into the recess

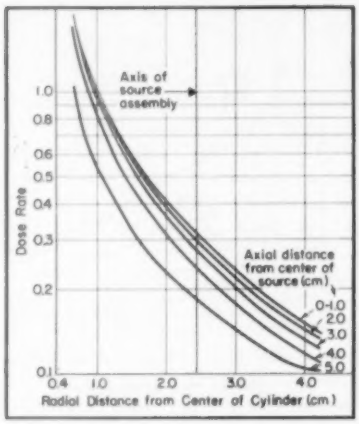


FIG. 4. Calculated dose rate in 10^6 r/hr from single cylinder as a function of position

at the top of the test hole, the source control is unlocked and the indexing pin is locked. With the source anywhere but in its uppermost position, the inner shield is locked in down position. If power fails during an exposure, the source can be raised to up position, where it is automatically locked. This is the only operation possible. If the power fails in up position, the indexing pin can be lowered but the inner shield and the source rod remain locked.

Dose Rates

The intensity D (r/hr) in the interior of the source assembly was calculated by evaluating the volume integral $D = k\rho(\int dv/R^2)$, where k = intensity at 1 cm from 1 mc in r/hr, ρ = specific activity in mc/cm^3, dv = element of source volume, R = distance between dv and point in space. Self-absorption in the source and its container is neglected, but the decrease in the calculated dose rate by self-absorption is offset to some extent by the contribution from scattered radiation.

Spatial variation of dose rate to be expected from a single cylinder is

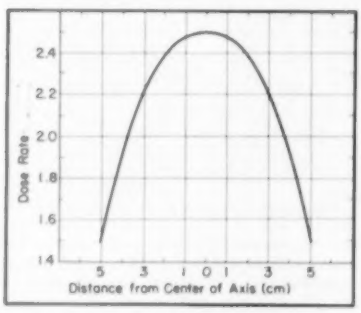


FIG. 5. Calculated axial dose rate within source assembly in 10^6 r/hr

How to assure performance you want from TEFLON®

IT'S SIMPLE. *Actually specify the properties* which are most important to you.

This is vitally important. Too often the properties are taken for granted. Yet with Teflon, the properties you get depend greatly on the method of processing the powder, which in turn governs the quality achieved.

In a choice of two grades, Fluoroflex®-T delivers the optimum properties you specify for Teflon. Quality is controlled under an exacting process.

"Electrical grade" Fluoroflex-T is *certified* to conform fully to AMS 3651 on all important electrical and physical properties. With optimum dimensional stability and free from pin-holes or porosity, it meets the most demanding service.

A more economical "mechanical grade" meets all chemical and mechanical needs. It offers as much as 50% greater resistance to elongation.

Fluoroflex-T is stress-relieved to assure uniform machinability. Large range of sizes available in rods, sheets, tubes. Send for data.

® DuPont trade mark. • ® Resistoflex trade mark.

RESISTOFLEX
CORPORATION

Roseland, N. J. • Western Plant: Burbank, Calif.
Southwestern Plant: Dallas, Tex.

WAREHOUSING DISTRIBUTORS: Chicago, Ill.—Colonial Kolonite Co.; Flow Products, Inc. • Detroit, Mich.—F. B. Wright Co. • Hartford, Conn.—Industrial Safety Supply Co. • Houston, Tex.—Lone Star Rubber Co. • Los Angeles, Calif.—Western Fibrous Glass Products • New York, N. Y.—Allied Plastics Supply Corp. • Norwood, Mass.—Laminated Sheet Products Corp. • Pittsburgh, Pa.—Shields Rubber Corp.

NUCLEONICS says:

"This book is exceedingly helpful to nuclear newcomers, also quite interesting for business and industrial people already involved in the atomic energy industry."

Atomic Energy for Your Business

TODAY'S KEY TO TOMORROW'S PROFITS

By ARNOLD KRAMISH and EUGENE W. ZUCKERT. Two well-known authorities explain the problems of peaceful uses of atomic energy, its potential application, what it means to the businessman today and its future promise—in language the layman can understand. *At all bookstores or use the convenient coupon below.*

CLIP THIS

DAVID McKAY COMPANY, Inc. N-4
55 Fifth Ave., N.Y. 3
Gentlemen: Please send me postpaid copies of ATOMIC ENERGY FOR YOUR BUSINESS, price $3.95. I enclose $
☐ check ☐ m.o.

Name .....
Address .....
City .....Zone.....State.....

OPPORTUNITIES
in
RADIATION
DOSIMETRY

For Chemists, Physicists and Electrical Engineers

To develop and use Material Dosimeters.

●

Knowledge of Nuclear Physics or Radiochemistry needed.

No previous experience in Dosimetry required.

●

This is a staff position which will challenge the most vivid imagination.

Please send resumé of education and experience to Staff Employment Section 565

SANDIA
CORPORATION
Albuquerque, New Mexico

shown in Fig. 4, and the dose rate along the axis, eight times the intensity indicated in Fig. 4, is shown in Fig. 5. The dose rate in the plane of the perpendicular bisector of the axis of the source assembly, computed by summing the contribution from each of the eight sources at a particular point, is shown in Fig. 6.

The calculated dose rate at the geometric center of the source assembly is 2.51×10^6 r/hr. The parameters illustrating the dose-rate uniformity available from this cylindrical arrangement of the radiation source are as follows:

	If maximum variation is	
	± 10%	*± 25%*
Average intensity (r/hr)	2.56×10^6	2.61×10^6
Diameter (cm)	2.3	3.0
Height (cm)	5.6	8.3
Volume (cm³)	23	60

Measured Dose. The maximum intensity attainable within the Co^{60} source was determined experimentally with ferrous-sulfate and ceric-sulfate chemical dosimetry. Values and method were those employed by Hochanadel and Ghormley.* The average maximum intensity, September 1954, was 2.5×10^6 r/hr, confirming the calculated value above.

Ceric sulfate was used to determine that a 3-liter aqueous sample (a cylinder 6 in. in diameter and 7 in. high) received an average dose of 10^4 r/hr when it was placed at the bottom of one of the wells and the source was completely withdrawn into the dome.

Intensities at various positions intermediate between the two extremes described above were determined experimentally with ferrous sulfate. All of the exposures were done in Lucite capsules 1 in. high and 1 in. in diameter containing approximately 5 cm³ of the ferrous sulfate solution. The location of these capsules at the bottom of the exposure well and the relative position of the source are shown in Fig. 2. Measurements were made with the source at various heights of 0–12 cm as measured from the bottom of the well to the bottom of the cobalt source. The source begins to enter the lead shield when this distance exceeds 12 cm, and scattering results in nonuniform irradiations unless the sample covers the entire bottom of the well. Thus these determinations were all made with the source outside the shield. Figure 7 shows the variation of dose rate as a function of horizontal displacement of the receptor and of vertical source height. Each experimental point represents the average of two or three runs.

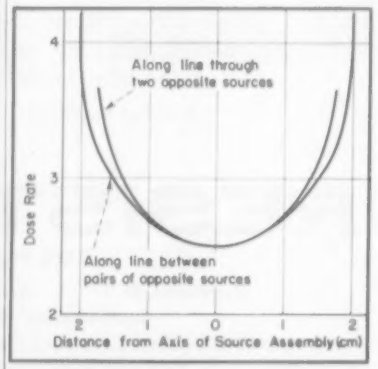


FIG. 6. Calculated dose rates inside the source along two perpendicular bisectors of axis of assembly (10^6 r/hr)

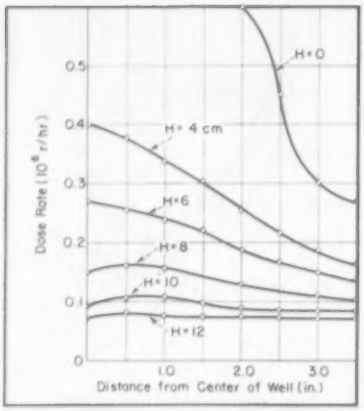


FIG. 7. Dose rate at bottom of well as a function of position and source height. These measured values show near uniformity when source is high

The maximum external radiation intensities are:

1. Adjacent to dome surface and base—0.1 mr/hr
2. At access conduit—0.3 mr/hr
3. Above dome—1.5 mr/hr
4. Over-all maximum (gap between casket and base with source opposite) —15 mr/hr.

* * *

This paper is based on work performed under Contract AT-11-1-Gen-8 between the U. S. Atomic Energy Commission and Atomics International. The authors wish to acknowledge the design help rendered by Dr. M. Feldman and Dr. M. A. Greenfield and to thank R. L. Ashley and S. Berger of this laboratory for their part in the calculations and dosimetry.

* C. J. Hochanadel, J. A. Ghormley, *J. Chem. Phys.* **21**, No. 5, 880 (1953)

Britain Begins Cs^{137} Therapy

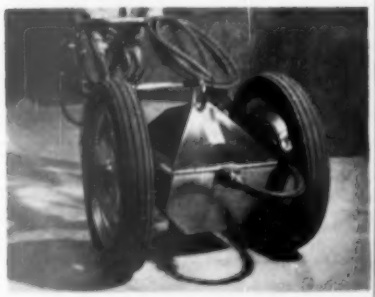
New large-scale extraction techniques have led to Britain's first large Cs^{137} installation. A 1,200-curie source is now in use in the Department of Physics of the Institute of Cancer Research at Royal Marsden Hospital, London. W. V. Mayneord is head of the department.

Scientists from Amersham, Windscale, and Harwell combined efforts to develop means to extract cesium from radioactive wastes. The source they produced contains a volume of cesium salt equal in size to four lumps of sugar. In the future a source of this type will be turned out each month. At this rate 2 years will be required to meet the present demand.

The first source has been encapsulated in a platinum cylinder 7 cm long and 3 cm in diameter and shielded in lead and uranium. Curved tungsten plates moving around the surface of a sphere form the shutters.

Meanwhile the AEC's multicurie fission-products pilot plant is nearing completion at Oak Ridge. It appears that the installation will be placed in operation next fall. The plant will be capable of separating and packaging 200,000 curies of Cs^{137} a year as well as large quantities of Sr^{90} and other potentially useful isotopes.

ORNL has delivered two Cs^{137} sources larger than the British one. In 1954 a 1,540-curie source was installed in a teletherapy unit at the medical division of the Oak Ridge Institute of Nuclear Studies. In 1956 a 2,000-curie source went to the fission-product-utilization program at the University of Michigan.



PORTABLE CO^{60} UNIT, called world's most powerful "portable" radiography source, was made by Budd Co. for Newport News Shipbuilding and Drydock Co. A 50-curie Co^{60} source can be uncovered by operator standing 50 ft away

PREFERRED

During the past 5 years, the proven performance of the EKCO Model 1079-C Vibrating Reed Electrometer has made it preferred by actual users, both here and abroad.

Low in cost, compact, rugged and easily serviced; its high, full-scale sensitivity and inherent stability makes the EKCO Model 1079-C ideal for all applications involving small current and voltage measurements.

STABILITY:	± 1 mv, day-to-day.
SENSITIVITY:	0.03 μμa full-scale reading @ max.
RANGES:	0-30, 0-100, 0-300, 0-1000 mv.
INPUT:	Internal, switch-controlled, 10^8, 10^{10}, 10^{12} ohm resistors.
OUTPUT:	Operates with 1 ma or 100 mv recorder.
POWER:	110/120 or 200/250 v, 40/60 cps, 40 w.
WEIGHT:	Only 29 lbs., complete with cables.

Write TODAY for Bulletin L-572 for complete data

AMERICAN TRADAIR CORP.
34-01 30th Street, Long Island City 6, N. Y. • Dept. N4
U.S. SALES & SERVICE for
EKCO ELECTRONICS, LTD., Essex England

Specialists in the Unusual

Precision Produced MATERIALS for TRANSISTORS and DIODES

- **GOLD** doped with N-type or P-type elements—supplied in the form of wire, sheet or ribbon and cut or stamped pieces.
- **INDIUM** electroplated base or precious metal wires.
- **WELDED RIBBONS**—Dissimilar metal ribbons of the same width can be continuously welded together, within close overlap tolerances.

Write for List of Products

Since 1901

SIGMUND COHN CORP.
121 SOUTH COLUMBUS AVE., MOUNT VERNON, N. Y.

BOOKS

Annual Review of Nuclear Science, Vol. 6, 1956

Edited by J. G. BECKERLEY, M. D. KAMEN, and L. I. SCHIFF (Annual Reviews, Inc., Palo Alto, Calif., 1956, vii + 471 pages, $7.00).

Reviewed by BERNARD MANOWITZ, Brookhaven National Laboratory, Upton, N. Y.

It seems somewhat incongruous to review a collection of reviews. It is probably of value, however, to point out to readers of NUCLEONICS the sections of this year's "Annual Review of Nuclear Science" that are of particular interest to the various disciplines in the field.

From a nuclear engineer's point of view, the outstanding chapter is the one by Harvey Brooks on *Nuclear Radiation Effects on Solids*. The article begins with a review of the status of the theory of atomic displacements with special emphasis on recent modifications and on critical experimental tests on the theory. The second section of the article is devoted to the recently declassified results in graphite and uranium. The final section is devoted to detailed reviews of recent work on metals and alloys, valence semiconductors, other valence crystals, and ionic crystals.

The article is clear and concise. The reviews are piercing and constructive. The article is an excellent and useful summary of the present status of solid-state physics.

Davidson, Loeb, and Young have assembled some qualitative data on reactor types in an article entitled *Nuclear Reactors for Electric Power Generation*.

The physicist will be interested in articles on primary cosmic radiation, a review of the basic theory of fast nuclear polarization, a review of nuclear excitation by heavy charged particles, and two chapters on nuclear data (nuclear masses and characteristics of medium-weight nuclei).

Three chapters are of interest to the chemist. A short review of recent advances in low-level counting techniques, a review of the generalized acidity concept as applied to radiochemical separations, and a review of the application of oxygen isotopes in chemical studies. Taube's article on oxygen isotopes stresses the study of chemical phenomena in homogeneous solutions. It is an impressive summary of the value of this tool in exposing the mechanism of reactions in solution.

The radiobiology chapters conclude the volume. The status of both cellular and vertebrate radiobiology are reviewed.

As with previous volumes of the "Annual Review," all articles are replete with references. Along with its predecessors, this volume provides a ready review of a field and a valuable source of bibliographies.

BOOKS RECEIVED

Report on the Atom, 2nd ed., by Gordon Dean (Alfred A. Knopf, Inc., New York, 1957, vii + 367 pages, $5.00). (*To be reviewed.*)

Progress in Nuclear Energy, Series 8, Vol. 1—The Economy of Nuclear Power, ed. by J. Gueron, J. A. Lane, I. R. Maxwell, and J. R. Menke (McGraw-Hill Book Co., Inc., New York, 1957, xii + 513 pages, $17.00). (*To be reviewed.*)

Optics, by Bruno Rossi (Addison-Wesley Publishing Co., Inc., Reading, Mass., 1957, xii + 510 pages, $8.50). This book, based on the wave model of light, acquaints the reader with light phenomena and the basic concepts underlying their interpretation. It concludes with a chapter on light quanta.

The Calculation of Atomic Structures, by Douglas R. Hartree (John Wiley & Sons, Inc., New York, 1957, xiii + 181 pages, $5.00). This book is concerned only with calculation of the outer electron structure of atoms. The reader should know something of waver mechanics up to the theory of the hydrogen atom.

Actions Chimiques et Biologiques des Radiations, edited by M. Haissinsky (Masson et Cie., Paris, 1956, vi + 223 pages, paperbound—$8.00, clothbound—$9.70). Second of a series, this book contains three articles: "Chemical Effects Produced in the Gaseous Phase by Ionizing Radiation," by W. Mund; "Luminescent Phenomena Produced by High Energy Radiation," by M. Ageno; "Introduction to Radiation Dosimetry," by N. Miller. All are in French.

Cours de Mathematiques, by J. Bass (Masson et Cie., Paris, 1956, xi + 916 pages, $22.25 and $24.25). A tremendous French tome, this volume includes most of the mathematics of advanced physics and engineering. Applications, methods of numerical calculation, and problems are included

Handbuch der Physik, Vol. XXXV, Atoms I, edited by S. Flugge (Springer-Verlag, Berlin, 1957, 454 pages). This volume of the Encyclopedia of Physics has just two articles, and both in English. "The Fundamental Constants of Atomic Physics" by E. R. Cohen and J. W. M. DuMond occupies the first 87 pages, and "Quantum Mechanics of One- and Two-Electron Systems" by H. A. Bethe and E. E. Salpeter fills the rest.

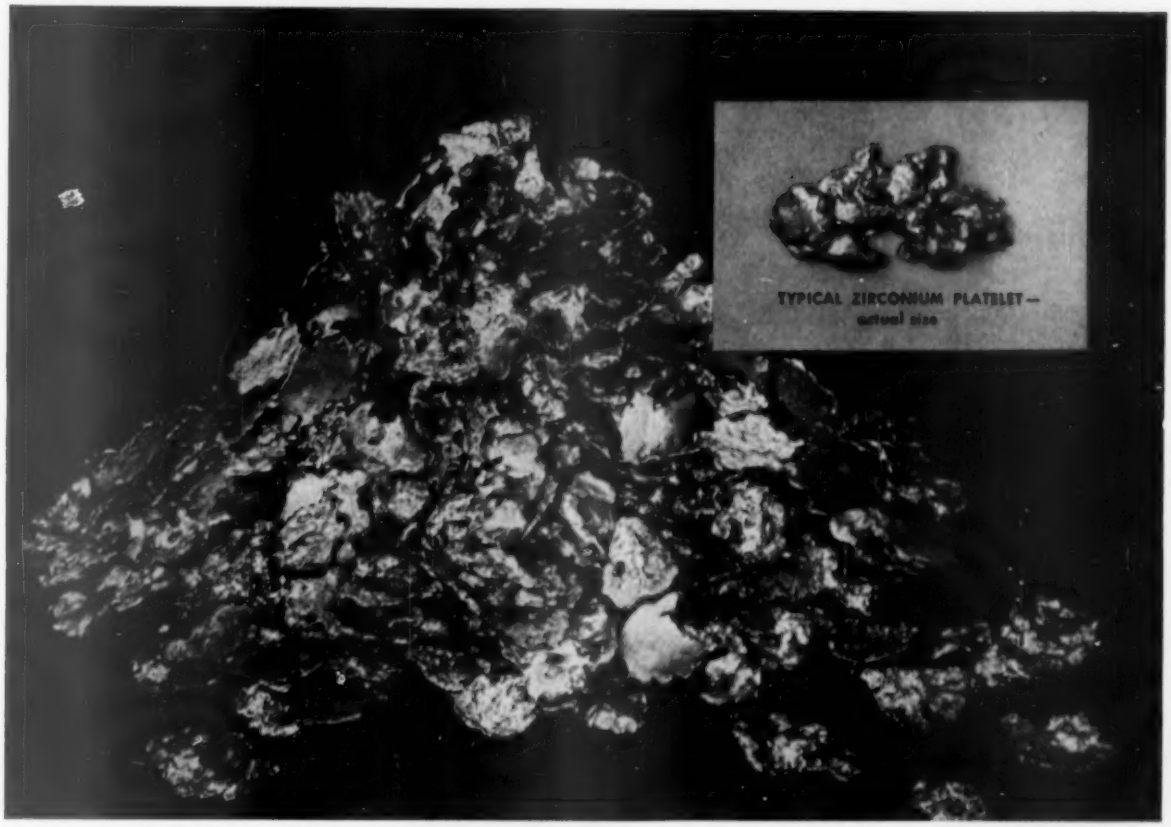
ALSO OF NOTE

The National Research Council Review, 1955. This review, NRC No. 3678, chiefly describes work during the year ended Dec. '54, with description of some later work. *National Research Council, Ottawa, Canada, $0.75.*

Trilinear Chart of Nuclides. This second edition of the chart, by W. H. Sullivan of Oak Ridge National Laboratory, is somewhat larger and in black and white instead of color. If warranted by demand, it will be kept up to date by issuance of gummed, hexagonal sheets. Information on nuclides available by July '56 is included. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $2.00.*

Charged Particle Cross Sections (LA-2014). Twenty-one physicists of the Los Alamos Scientific Laboratory compiled this data. It includes the best cross sections of all nuclear process involving charged projectiles with energies up to about 30 Mev, and it is limited to light-element targets up to and including fluorine and to incident particles with mass one through four. The scope should be extended by later editions. Presentation is graphical. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $1.25.*

Geologic Investigations of Radioactive Deposits (TEI-590). This semiannual progress report of the U. S. Geological Survey, prepared for the AEC, reviews investigations of radio-



Available soon at lower prices . . .

A MILLION POUNDS OF ZIRCONIUM FOR INDUSTRIAL USE

By mid-1957 zirconium users can get 1,000,000 lbs. a year of the metal from a new U.S. Industrial Chemicals Co. plant at Ashtabula, Ohio. In a new, non-pyrophoric, non-hygroscopic platelet form U.S.I. zirconium has these advantages over the more familiar sponge metal: it eliminates safety problems in handling and shipping, and it permits a cleaner, safer melting operation.

Lower Price

Reactor grade will be priced at $4.75 to $6.50 a pound, depending on quantity. Commercial grade will sell at about $1.50 less. These low prices will be possible because U.S.I., as a prime producer of sodium metal, uses a semi-continuous sodium reduction process—the most economical production technique ever developed for reducing metallic chlorides.

Higher Quality

U.S.I. zirconium will offer users top-quality, too. In the first place, U.S.I. starts with sodium, a higher purity raw material than the reducing agents commonly used in other processes. Then, the technique itself yields a product of higher purity and uniformity. Finally, in making its zirconium platelets U.S.I. virtually eliminates chloride, magnesium, sodium and hydrogen impurities.

Small quantities of commercial grade material are available for immediate delivery. To help you on applications U.S.I. has a staff of metal experts. Call Bill Greenleaf, Manager of Metals Department, for further information.

Chemical Progress Week — April 8-12

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers Products Corp.
99 Park Avenue, New York 16, N. Y.

careers in the peaceful applications of atomic energy

PHYSICISTS

For senior research positions. Advanced degree or experience in related fields desirable.

THEORETICAL

Develop theoretical methods for the treatment of new and unique problems in reactor criticality and kinetics, thus providing a scientific base for the development of nuclear reactors.

EXPERIMENTAL

Perform and analyze neutron physics experiments to provide basic physics data for the study of new reactor concepts. Also, to investigate the nuclear behavior of advanced reactor prototypes and zero power critical experiments.

Write: Answer will be prompt and confidential

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

Mr. G. W. Newton, Personnel Office, Dept. C-4
21600 Vanowen Street, Canoga Park, California
(In the Suburban San Fernando Valley, Los Angeles)

active deposits in the U. S. and Alaska from June 1 to Nov. 30, 1955. 340 p. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $1.50.*

IBM Journal of Research and Development. This new quarterly, published by IBM starting Jan. '57, will contain original articles by its staff. Subjects will include basic research as well as computing machines and components. *International Business Machines Corp., 590 Madison Ave., New York 22, N. Y., $3.50 per year.*

Nuclear Data Cards. Because of the popularity of these monthly card sets, which were started in 1954, subscription rates have been reduced: $15, U. S., its territories, and Canada (first-class mail); $15, elsewhere (printed-matter mail); $19, elsewhere (first-class mail). Airmail subscriptions will be arranged on request. *Publications Office, National Academy of Sciences-National Research Council, Washington 25, D. C.*

Calculated Efficiencies of NaI Crystals (PB 121419). The probabilities for interaction of gamma rays with NaI crystals are calculated for a point isotropic source on the axis of a cylindrical crystal. Results for 18 commercially available crystal sizes and a wide range of energies and source-to-crystal distances are presented in tables and graphs. 40 p. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $1.00.*

Uranium Deposits at Base of the Shinarump Conglomerate, Monument Valley, Arizona (Geological Survey Bulletin 1030-C, $0.65); **Accuracy of Ore-Reserve Estimates for Uranium-Vanadium Deposits on the Colorado Plateau** (Bulletin 1030-D, $0.45); **Study of Radioactivity in Modern Stream Gravels as a Method of Prospecting** (Bulletin 1030-E, $0.25); **X-Ray Powder Data for Uranium and Thorium Minerals** (Bulletin 1036-G, $0.25). These bulletins are prepared by the U. S. Department of the Interior for the AEC. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

Proceedings of the Second RETMA Conference on Reliable Electrical Connections. Proceedings covers techniques, tools, materials, and measurements. 103 p. *Engineering Publishers, Box 1151, New York 1, N. Y., $5.00.*

THE 2ND INDUSTRIAL NUCLEAR TECHNOLOGY CONFERENCE

ON NON-POWER ASPECTS OF NUCLEAR TECHNOLOGY

Co-sponsored by: ARMOUR RESEARCH FOUNDATION and NUCLEONICS Magazine

Time: May 14, 15, 16

Place: Museum of Science and Industry, Chicago, Ill.

May 14th, morning:

NUCLEAR SCIENCE FOR EXECUTIVES

Properties of Radioisotopes
Interaction of Radiation with Matter
Radiation Detection and Measurement
Elements of Radiation Hygiene

May 14th, afternoon:

COMPANY NUCLEAR PLANNING

What Has Been Done with Radiation
Radiation Sources and Costs
Laboratory Facilities and Staff Requirements
Administrative and Legal Problems

May 15th, morning:

NUCLEAR TECHNOLOGY APPLICATIONS

Some Uses of Separated Stable Isotopes
Radioactive Tracers in Ore Dressing Systems
Particle Size Determination by Radioactivation
Potentialities of Low Energy Isotopic Radiography
Density Measurements with Thulium 170
Scintillator-Photocell Nuclear Battery
Neutron Absorption in Glass-Reinforced Laminates
Textile 'Plastic Starch' Durability by Tracer Techniques

May 15th, afternoon:

RADIATION CHEMISTRY

Energy Loss of Charged Particles in Molecular Substances
Irradiation of High Polymers
Mechanism of Radiation Effects in Polyethylene
Radiation Chemistry of Aqueous Solutions
Effect of Displaced Atoms and Ionizing Radiation on Oxidation of Graphite
Production of Radioactive Molecules Through Reactions of Energetic Atoms and Ions
Carbon-14 Labelling of Hydrocarbons by Nuclear Recoil
Organic Radiation Effects (invited)

May 15th, afternoon:

NUCLEAR INSTRUMENTS

Helical Orbit Beta-Ray Spectrometers
Some Research Uses of a Zero Power Reactor
Beta-Ray Spectroscopy Using Plastic Scintillators
Neutron Spectroscopy With Proportional Counters
Radiation Detection With Spark Counters
Circuits for Pulse Height Analysis
Recent Trends in Nuclear Instrumentation (invited)

May 16th, morning:

RADIATION SOURCES AND EFFECTS

A Cobalt Irradiator
Effects of Nuclear Irradiation on Magnetic Materials
Radiation Polymerization Dosimetry
A High-Output Light-Weight 15 Mev Betatron
Radiation Effects in Electronic Devices
Pressurized High Frequency Cockcroft-Walton Accelerator
Industrial Applications of Linear Electron Accelerators
Economics of Electron Beam Irradiation
Glass Radiation Damage (invited)

May 16th, afternoon:

NUCLEAR TECHNOLOGY APPLICATIONS

Radioactivity Gauge Measures Level Over 45 Feet
Electroplating and Metal Preservation Studies Utilizing Radioisotopes
Some Limitations on the Use of Neutron Activation Analysis
Beryllium Hazard Detection Using Polonium
Dyeing of Synthetic Fibers with Radiation
Radioactive Meteor Erosion Gauge for Earth Satellites
Proportional Counter X-Ray Absorptiometry for Organic Analysis
Low Level Counting (invited)

A banquet will be held on May 15 and conference luncheons on May 15 and 16.

For further information, contact:

L. Reiffel, Conference Co-chairman
Armour Research Foundation
3440 S. State
Chicago, Ill.

9 ways better at watching over you

Picker Gardray Radiation Badges

1 wide intensity range
Records exposures low as 50 mr, high as 300,000 mr.

2 wide energy range
Gamma, beta, x-rays (soft and hard) neutrons, single or mixed exposures.

3 "control" safeguard
Separate control badge guards against accidental fogging.

4 double-sure identification
1 code printed on wrapper
2 x-rayed on film

5 no loading or unloading
Wear badge as received, return it intact.

6 prompt reporting
Dependable, easy-to-read, too.

7 compact, lightweight
See size above: less than 1 oz.

8 attractive, unobtrusive
Clips on firmly, won't catch clothing.

9 durable
Secure snap-locks, won't come undone, won't break.

To subscribe, call any Picker X-Ray local office (see your 'phone book) or write to Picker X-Ray Corporation, 25 So. Broadway, White Plains, N.Y.

LETTERS

Nitrogen Fixation

DEAR SIR:

I have read the article "Producing Chemicals with Reactor Radiations" by Harteck and Dondes (NU, July '56, p. 22; letter, Dec. '56, p. 77) with great interest since I have been associated with the Wisconsin process for nitrogen fixation for a number of years.

The work that the authors have done in their experimentation is noteworthy, but at the moment the commercial significance escapes me for the reasons outlined in the following paragraphs.

The nitric acid equivalent of 70,000 tons of N as NO_2 is 315,000 tons of 100% HNO_3. The cost of nitric acid is based on 100% equivalent acid and not, as the authors have assumed, upon 38 deg Baumé acid. Using their figures, one can readily arrive at $60-million sales, but it is incorrect.

The price given by *Chemical and Engineering News* is $6.25/100 lb or $125/ton—but this price is for carboys. Nitric acid for chemical use in tank-car shipments runs about $60/ton of 100% equivalent HNO_3 or $17-million, using a 90% recovery efficiency on the NO_2 produced. However, the major nitric acid use is in fertilizer manufacture, and a still lower price would be required such as $40/ton or total sales of $11,300,000 in contrast to the $60-million claimed as the value.

As NO_2, the product might be worth $10-million if there were a market. At the moment, there is only a small market for NO_2. Markets could develop for NO_2 as a nitration material, but it would have to compete with the lower-cost nitric acid.

With respect to the value given of $15-million as fertilizer, the sales price of ammonia and ammonium nitrate is equivalent to 5¢ and 10¢/lb N, respectively, or $7-million to $14-million sales value. The higher figure is approximately as given by the authors.

The cost of uranium alone at $6-million is equivalent to $19/ton of 100% nitric acid. Present *total* operating costs for nitric acid plants in the 200-ton/day class, much smaller than that visualized by the authors, is of the order of $20/ton of 100% nitric acid. No doubt there are residual values to be obtained from the spent uranium, but it would be difficult to beat present technology.

As a final point, the heat at 200° C is indicated as equivalent to 500,000 tons of coal. This no doubt is true on a theoretical basis, but does not enter into the economic picture, since it is essentially unavailable. The capital investment required to capture a portion of this heat would be too great for economical recovery.

From a technical standpoint, the authors' work is excellent, but I disagree with the economic implications—that here is a project ready to exploit now. In fact, from a commercial standpoint, it has a long way to go.

—E. D. ERMENC
Princeton, New Jersey

DEAR SIR:

We would like to thank the editors of NUCLEONICS for the opportunity to reply to the letter from Mr. Ermenc.

In preparing the manuscript on "Producing Chemicals with Reactor

Comparison of Prices*

Product	*Market price ($/short ton)*	*Chemical producer's price ($/short ton)*	*Nitrogen content (%)*	*Short tons of product (in thousands)*	*Market price value (in millions of dollars)*	*Chemical producers value (millions of dollars)*
NH_3	82.50	42.00	82.35	95.2	7.8	4.0
NH_4NO_3	64.00	39.00	35.00	224.0	14.3	8.7
HNO_3 (38° Baumé on 100% HNO_3 basis)	60.00	43.00	22.22	353.0	21.2	15.2
HNO_3 (fuming)	~150.00	~90.00	~22.22	~352.0	53.0	31.8
NO_2	~200.00	~120.00	30.43	257.6	51.4	30.9

* Based on 70,000 long tons (78,400 short tons) of nitrogen in product.

Radiations," we were faced with the problem of presenting the paragraph on the economics of the process to the varied audience of NUCLEONICS. For the readers who were not in the nitrogen industry, we used the readily obtainable values of price per pound or price per carboy and scaled them to our results. For the members of the nitrogen industry, who would compare our values with their own production costs in existing plants, a chemical producers' value per ton of fixed nitrogen was used, since we realized that simply to indicate market values would not suffice. (Chemical producers' values are normally company confidential material.)

It should be noted that the value of the fixed nitrogen presently produced in the United States is about 10% of the value of the electrical power production.

Almost 100% recovery efficiency should be possible from nitrogen dioxide, rather than only 90% as shown by Mr. Ermenc. The value of 70,000 tons of nitrogen as nitrogen dioxide is given in long tons, so that this figure must be multiplied by 1.12 for conversion into short tons.

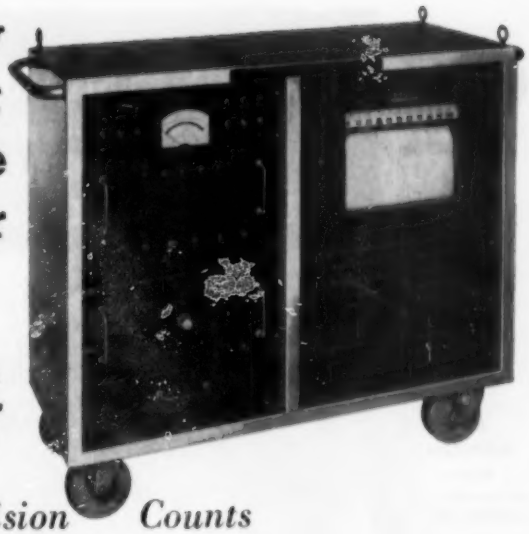
In the table on p. 124, the market and chemical producers' values are enumerated for a number of nitrogen products. For comparison with Mr. Ermenc's values, the market and chemical producers' values are given per short ton in tank-car shipments. The market value for nitric acid for chemical use in tank-car shipments is given as $60 per ton of 100% equivalent HNO_3, Mr. Ermenc's value. The chemical producers' value for the nitric acid is an average of a number of companies' values based on operating costs (i.e., cost of ammonia, electric power, water, labor, catalyst, and maintenance) and averages about $43 per ton. From this table it can be readily seen that at the burn-up of $6,000,000 of uranium (shown in the article), all the products are economically feasible except ammonia.

Since the publication of the article, additional information has become available that improves the feasibility of the process. These are:

1. The price of uranium-235 has recently been lowered by the U. S. government from $25 to about $18 per gram (NU, Dec. '56, p. R1). The value of $25 per gram was used in the article. The $6,000,000 fuel burn-up is therefore only $4,320,000.

2. In a forthcoming article, in

New Air Particle Monitor



from **ANTON**

..Where Precision Counts

Anton's monitor enables continuous, unattended recording of airborne alpha, beta or gamma radiation with sensitivity never before available in instruments of this type. The monitor, ideal for reactor, fuel processing and hot lab installations, can operate at gamma background as high as 10 mr /hr. The unit has a sensitivity range of 8 x 10^{-10}μc /cc to 8 x 10^{-7}μc /cc as calibrated with Na^{24}, and incorporates visible and audible, immediate or remote alarms adjustable over the operating range. Built-in calibrated source insures accuracy and performance of the instrument's detector and related circuitry. Special circuit failure indicator check switch connects the panel meter to key circuit points for easy trouble shooting. Anton monitoring instruments and systems include the latest developments resulting from fundamental research work on system production for reactor facilities and naval nuclear-powered vessels.

Anton's monitor is available either as a cart-mounted mobile unit or rack-mounted for use as a fixed station. Mobile unit, MODEL 232, is set on a welded, reinforced steel cart; MODEL 233 has all equipment mounted in a 19-inch relay rack. (*Request Bulletins 232, 233*)

TECHNICAL DATA

Precision	**Better than 1% of full scale meter deflection**
Stability	**Better than 0.5% of full scale meter deflection**
Filter paper advance	**Continuous: at ½ inch/hour**
	Manual (when necessary): by external control knob
Pulse discriminator	**Rejects small "noise" pulses**
Air pump	**Positive displacement, oil-less, requires no lubrication**
Recorder	**12 inch chart, speed adjustable from ½ to 8 inches per hour**
Power	**Nominal 117 v, 60 c.p.s.**
Weight	**Net 450 lbs.**
	Shipping 500 lbs.

TRAILER-MOUNTED SURVEY LABORATORIES

This monitor is incorporated in the new Anton mobile radiological laboratory trailers which contain complete field equipment for reactor site survey teams, fire fighting, police and civilian defense forces. (*Request Bulletin TM*)

Anton also manufactures a full line of tubes and instruments for research, medical and industrial counting applications. (*Request Bulletin 4P*)

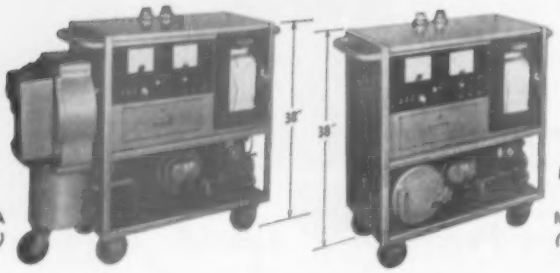
ANTON ELECTRONIC LABORATORIES, INC.

A subsidiary of U. S. Hoffman Machinery Corporation

1226 FLUSHING AVE., BROOKLYN 37, N. Y.

NMC
INDIANAPOLIS

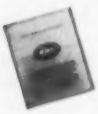
COMPLETE MONITORING SYSTEMS
for radioactive
AIRBORNE PARTICLES · GASES
WATER CONTAMINATES (Soluble or Suspended)



α,β,γ AIR MONITOR Mobile Model AM 3-A (moving filter)

β,γ AIR MONITOR Mobile Model AM 2 (fixed filter)

- Records and warns automatically for periods up to one week, unattended.
- Complete monitoring systems or individual units (illustrated) assembled from standard components.
- Custom built to solve any monitoring problem.
- Designed for absolute containment of sampled radioactivity.
- NMC professional consultation included with each instrument.



Send for FREE CATALOG

Nuclear Measurements Corp.
2460 N. Arlington Ave. • Telephone: LIBERTY 6-2415
INDIANAPOLIS 18, INDIANA
International Office: 13 E. 40th St., New York 16, N.Y.

careers in peaceful applications of atomic energy
COMMERCIAL REACTOR OPERATIONS

Experienced Reactor Operations Engineers needed for a new section engaged in developing procedures, testing, training personnel and the start-up of foreign and domestic power and research reactors. A minimum of a BS in Engineering or Physics with several years operations experience is required for this program based on established contracts.

Write today. Action will be prompt, confidential

AI ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
Mr. G. W. Newton, Personnel Office, Dept. C-4
21600 Vanowen St., Canoga Park, California
(In Suburban San Fernando Valley, Los Angeles)

NUCLEONICS, one method for the solution to the problem of dispersing uranium is set forth.

3. From additional new experimentation, larger yields of fixed nitrogen are being obtained, exceeding the 70,000 long tons (78,400 short tons), and approaching 98,000 long tons (109,800 short tons), decreasing the costs by about 28%.

4. With increasing development of reactors, the investment costs of reactors are decreasing.

5. The costs of replacement nitrogen-fixation plants, together with operating costs, are increasing.

We agree with Mr. Ermenc that at present the process has not been sufficiently developed for immediate application. However, from all the advantages enumerated, one must conclude that nitrogen fixation by reactor radiation is economically feasible for the production of nitric acid and its derivatives and should be used in the near future.

—PAUL HARTECK and
SEYMOUR DONDES
Department of Chemistry
Rensselaer Polytechnic Institute
Troy, New York

Shielding Computations

DEAR SIR:

In reference to B. F. Binford's article, other literature should be noted: "The Reactor Shielding Design Manual" by Rockwell, "The Functions $E_n(x) = \int_1^\infty du e^{-xu} u^{-n}$" by Placzek, and "A Table of Integrals Involving the Functions $E_n(x)$" by J. LeCaine.

The last two documents rather thoroughly explore the properties of the E functions and include tables of values as well as tables of integrals involving E functions. The E-functions are, of course, the same as the F-functions.

—MARSHALL GROTENHUIS
International School of Nuclear Science and Engineering
Argonne National Laboratory
Lemont, Illinois

DEAR SIR:

It seems to me that, in the note by F. T. Binford (NU, Dec. '56, p. 62), his function $F_n(x)$ is identical with a well known function $E_{n+1}(x)$ defined by

$$E_n(x) = \int_1^\infty \frac{e^{-tx}\,dt}{t^n}$$

The E_n functions are the subjects of

two extensive reports originally published by Chalk River—one by G. Placzek (MT-1, NRC-1547) and the other by J. LeCaine (MT-131, NRC-1553). The former lists values of these functions for $n = 0(1)20$; $x = 0(0.01)2.0(0.1)10$, as prepared by the old WPA Mathematical Tables Project. Placzek's report, including the tables, has been reprinted in part or whole in AMS-37, issued by the National Bureau of Standards, and in vol. 1 of "Introduction to the Theory of Neutron Diffusion" by K. M. Case et al., both of which are available from the Government Printing Office.

E. P. Blizard has printed graphs and tables of E_1, E_2, and E_3 out to $x = 20$ in ch. 2.5, vol. 1 of the "Reactor Handbook," while Foderaro and Obenshain have published graphs of E_1 and E_2 for x as large as 30 in TID-7004. Astrophysicists have also been greatly interested in the E_n functions, as witness for example the discussion in Kourganoff's "Basic Methods in Transfer Problems," Oxford U. Press, 1952.

The final equation in Binford's note is identical with Eq. 1c of Placzek's report. In reactor and shielding circles, the functions have been so closely associated with Placzek that I would like to campaign for having them denoted as the Placzek functions. It would be little enough to honor the memory of the eminent physicist we so recently lost.

—Herbert Goldstein
Nuclear Development Corp. of America
White Plains, New York

Dear Sir:

With respect to Dr. Goldstein's letter concerning the note on the F-functions, as anyone familiar with the subject is aware, he is perfectly correct in his statements concerning the identity of $F_n(x)$ and $E_{n+1}(x)$. We seem to differ only in our interpretation of the phrase "not extensively tabulated."

The purpose of the note was not to imply that the procedure outlined was a new one but merely to exhibit it where it would be readily available to persons not familiar with project literature. That this sort of thing is indeed worthwhile has been demonstrated by the large number of requests for reprints that I have received.

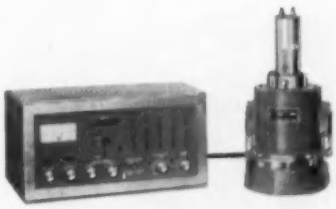
—F. T. Binford
Operations Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

NOW... A SCALER with 5 DECADE UNITS!

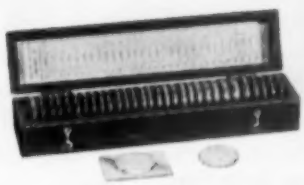
MODEL DS-5 DECADE SCALER

TECHNICAL ASSOCIATES has designed this general purpose nuclear laboratory counting instrument to combine extreme reliability and accuracy with unusual simplicity of operation. Five plug-in decade units permit a direct count up to 199,999, without the use of external registers. Overall resolution time is 1.0 microsecond per pulse pair. Pulse height control allows sensitivity to be varied to facilitate analysis of sample content. "Mono-matic" single lever control starts, stops, and resets count and time, thus simplifying operation and preventing errors.

DS-5 DECADE SCALER can be combined with other T/A accessories to form a complete Laboratory Counting System...

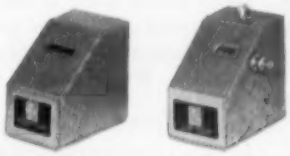


Model DS-5 Decade Scaler shown in use with Model LS-7M Lead Shield and Model SD-1 Scintillation Detector



Model AB-2 Calibrated Absorber Set

Write for complete catalog entitled "Instrumentation for Nuclear Research"

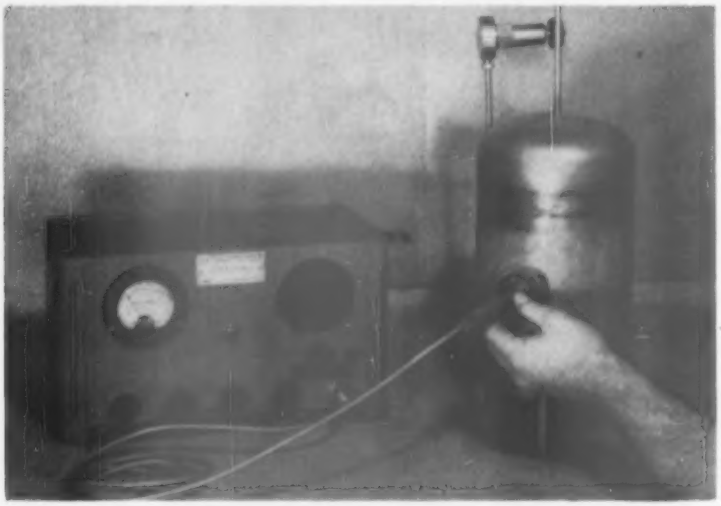


Model CR-1 Count Register and Model PT-1 Predetermined Timer

TECHNICAL ASSOCIATES
Instrumentation for Nuclear Research

140 West Providencia Avenue
Burbank, California

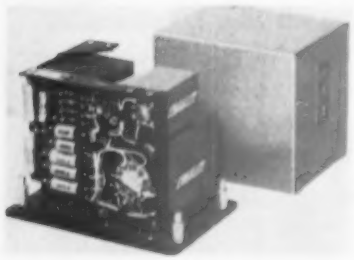
PRODUCTS AND MATERIALS



Liquid-Metal Level Indicator Uses Balanced Inductance Bridge

Shown above is a unit designed to monitor liquid-metal levels through use of an oscillator signal and a balanced bridge circuit sensitive to changes of inductance of a coil in the probe. It is sensitive to 1-mm height changes. As currently made it must be used with nonmagnetic containers, but circuit modifications can obviate this limitation. Variation in wall thickness can be allowed for by changing the signal frequency. Probes can be shaped as needed. Cost is $465.—Nuclear Development Corp. of America, 5 New St., White Plains, N. Y.

CONTROLLERS AND RECORDERS



Servo Amplifiers

Line of servo amplifiers are for 60- or 400-cps motors, shaft powers of 1–50 watts. Input networks are in three groups: single-speed synchro and pot, two-speed synchro, and d-c.—Industrial Control Co., Wyandanch, L. I., N. Y.

Curve Analyzer

Equameter GEQ-400 is an electrically driven analogue computer designed to analyze and plot curves. Analysis can be in terms of Fourier components or power series. Least-squares fits for 50 points to the fifth power are possible.—Gerber Scientific Instrument Co., 162 State St., Hartford 3, Conn.

Plug-In Totalizer

Model 166 provides accurate register in programs involving velocities, pressures, temperatures, flow rates, etc. Requires 15-volt, 1-volt/μsec, 100-μsec input.—Baird Associates-Atomic Instrument Co., 33 University Rd, Cambridge 38, Mass.

Thermistor Control

Sensitivity of thermistor bridge and dual indicating-controlling function of contact meter-relay are combined. Acts on temperature changes as small as 0.075° F.—Assembly Products, Chesterland, Ohio.

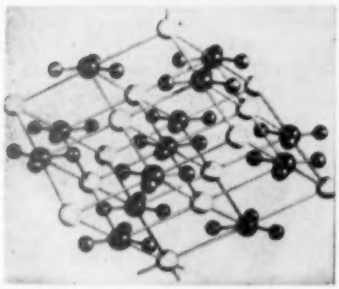
Two-Pen Recorder

Unit above uses 17.4 × 9.9-in. panel space and is 12.5 in. deep. Has 9 chart speeds, 2½-sec. pen speed, ranges of 10 mv or greater.—Westronics, 3,605 McCart, Ft. Worth, Texas.

Temperature Control

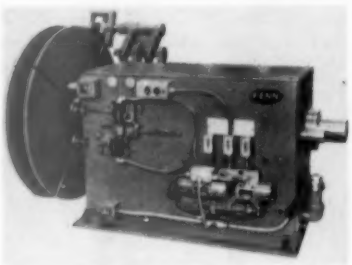
Multipoint pyrometer instrument controls 4–10 separate units. Combines null-balance potentiometer circuit and electronic speed. Several ranges available.—Thermo Electric Co., Saddle Brook, N. J.

LABORATORY INSTRUMENTS AND APPARATUS



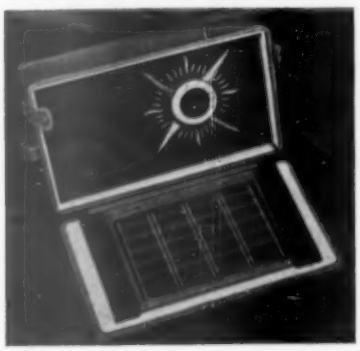
Crystal Models

Manufactured in Germany, crystal lattice models are based on X-ray and electron-diffraction data. Magnification is 250×10^6. More than 100 types available.—Arthur S. LaPine & Co., 6,001 S. Knox Ave., Chicago 29, Ill.



Takeup Reels

New line of takeup reels are for use with wire-flattening mills. Model 2310 (above) has 3-in.-diameter spindle, 10-in. stroke. Own motor and controls provide constant tension.—Fenn Mfg. Co., Newington, Conn.

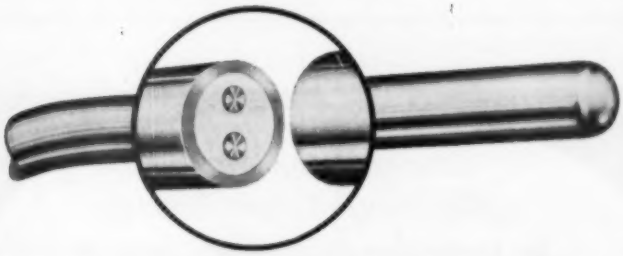


Sun Battery

SB-24B5 transforms solar energy to electrical power to power transitorized circuits. 24 photosensitive elements in series deliver 12 volts open circuit, 6 at maximum power.—International Rectifier Corp., El Segundo, Cal.

Longer Thermocouple Life In Atomic Reactors

With T-E Ceramo® Wire Thermocouples



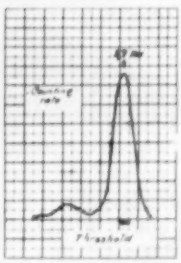
Designed for use under extremely severe conditions, enclosed hot-junction "Ceramo" thermocouples—with ceramic insulated, metal sheathed wire—will outlast comparable standard types many times. And response time is just as fast. Furthermore, both sheathing and insulation can be specially selected for resistance to atomic radiation. Conductors in all standard calibrations and various sheath materials are available for temperatures up to 3000° F. If desired, "Ceramo" thermocouples can be completely pre-tested. Conductors—36 to 12 gage. Overall diameters—1/25" to 7/16".

Write for Bulletin 305-K

Thermo Electric Co. Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

X-RAY, HIGH RESOLUTION, PROPORTIONAL COUNTERS

- Beryllium window: 18 mg/cm².
- CONTINUOUS PURIFICATION OF GAS FILLING BY HOT CALCIUM.
- GUARD RING AND FIELD RING, QUARTZ INSULATED give a very precise definition of the useful volume. This allows spectrometry of low energy electrons down to 0,2 KeV.
- RESOLUTION: 15% to 20% at 6 KeV.



ALL INSTRUMENTS FOR NUCLEAR PHYSICS LABORATORIES.

Societe D'Applications Industrielles de la Physique (S.A.I.P).

146, Bd de Charonne. PARIS XXe. FRANCE.

careers in the peaceful applications of atomic energy

Join a leader in research, development, design and manufacture of nuclear reactors for industry, power, medicine and scientific study.

METALLURGISTS

B.S., M.S., or PhD.—with training or experience in physical metallurgy of nuclear fuel materials; in metallography of both fuel and construction materials; in high temperature material (both alloy and ceramet) development and evaluation; in vacuum melting and casting techniques; or in mechanical fabrication related to fuel element manufacture.

MECHANICAL ENGINEERS

For development work in the Pyroprocessing Refabrication Experiment. To develop equipment for remote high temperature decontamination and remote refabrication of nuclear fuels.

Write: Answer will be prompt and confidential

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

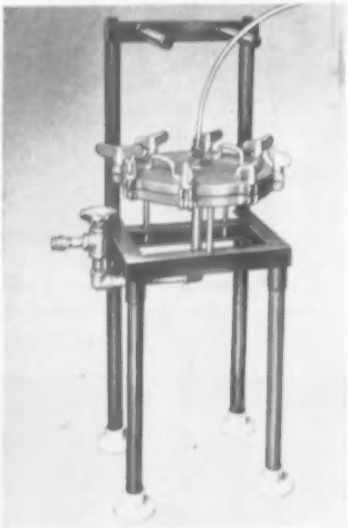
Mr. G. W. Newton, Personnel Office, Dept. C-4
21600 Vanowen Street, Canoga Park, California
(In the Suburban San Fernando Valley, Los Angeles)

Leakless Blower

Centrifugal blower and canned motor sealed in heavy stainless steel enclosure can handle radioactive gases at high temperatures and system pressure.—Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

Plug-In Kits

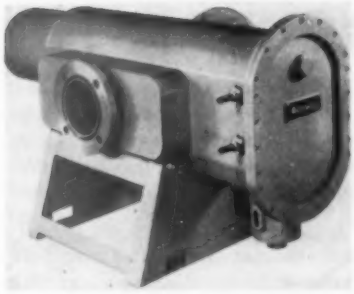
Assembly kit shown mounts 1-3 7- or 9-pin miniature sockets. Adaptor rings accommodate different diameters. Other models hold up to 5 sockets. Over-all height is 3 in.—Vector Electronics Co., 3352 San Fernando Rd., Los Angeles 65, Cal.



Submicron Filter

Particles as small as 0.45 microns can be quantitatively filtered out of water flowing at 100–400 gal/hr with new submicron filter. Element is 150-micron-thick cellulose ester disc with total pore volume of 80–85%.—Barnstead Still & Demineralizer Co., 222 Lanesville Terr., Boston 31, Mass.

Beta gage. Type 150 has 2 × 12-in. measuring area, variable response time (0.1–10 sec), remote indicating meter.—Isotope Developments, Ltd., Benham Grange, Berkshire, England.



Fast Vacuum Pumps

Roots-type vacuum pumps are available in 6 sizes with speed ranges of 92–4,900 cfm. Figure-8-shaped rotors counter rotate without touching. German-made.—Rochester Division, Consolidated Electrodynamics Corp., 1775 Mt. Read Blvd., Rochester 3, N. Y.

Ultrasonic Tools

Soldering iron (above) fills blow holes in aluminum castings, bonds aluminum cables, etc. Ultrasonic power transmitted through solder removes oxides to permit tinning. Ultrasonic drill will drill square holes in glass blocks, for example. Made in England by Mullard.—Acoustica Associates, Inc., Glenwood Landing, L. I., N. Y.

•

Nuclear Trail Plates. Plates with nuclear emulsions that have been exposed over Sardinia at 20-30-kilometre altitudes are available for research and instruction.—J. Klinger, 8287 160th St., Jamaica 32, N. Y.

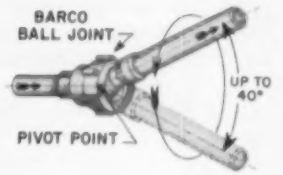
Copper dispersion. Dag 235 is colloidal-copper dispersion in lacquer for production of conducting surfaces.—Acheson Colloids Co., Port Huron, Mich.

Tank lining. Fairprene T-5594 synthetic rubber lining is available in 2-ply, ⅛-in., 50-in.-wide strips with primers and adhesives.—E. I. du Pont de Nemours & Co., Wilmington, Del.

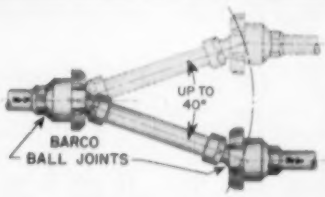
Here's How to Make Safe

COOLING LINE CONNECTIONS

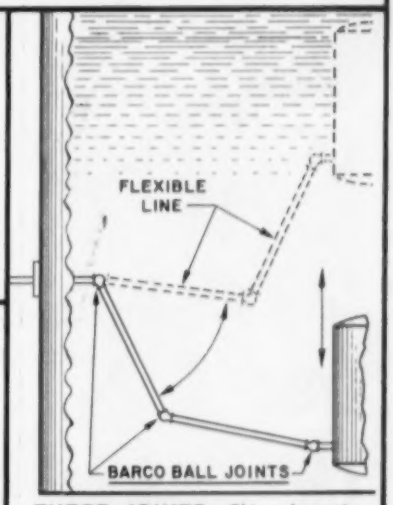
to Moving Reactor Components



ONE JOINT—Provides for angular motion or positioning of piping in any plane.



TWO JOINTS—This arrangement provides for piping alignment or simple flexible connection.



THREE JOINTS—This schematic diagram shows how "dog leg" piping assembly permits vertical movement of large equipment.

Barco Flexible Ball Joints for Nuclear Projects

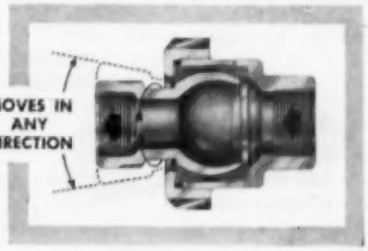
CERTAIN distinctive characteristics and features make Barco Flexible Ball Joints particularly well-suited for many nuclear energy applications:

1. Easy to engineer joints into piping to provide for any degree of flexibility, expansion, or movement required.
2. Seals unaffected by radioactivity.
3. All-metal construction. No ball bearings. No lubrication required. Special metals can be specified.
4. Basic design is pressure sealing against leakage and self-adjusting for wear.
5. Maximum safety for virtually any pressure and temperature conditions.
6. Usually no deterioration due to normal operation. Special activities may require special materials.
7. Special flexible joints for conveying fluids at low temperatures down to −300°F. Also high temperature designs up to +1000°F.

For information and recommendations on how to select, specify, and use Barco Joints, address letter to:

FOUNDED 1920
BARCO
PRODUCTS BACKED BY EXPERIENCE

BARCO
MANUFACTURING CO.
567E NORTH HOUGH STREET
BARRINGTON, ILLINOIS



whatever your publication needs . . .

Equipment Manuals — Product Catalogs – Handbooks – Training Aids – Industrial Relations Literature — Procedural Guides — Engineering Presentations — — — and any type of technical literature

use our specialists in — — —
WRITING . . . EDITING
ILLUSTRATING . . . PRINTING

McGRAW-HILL
Technical Writing Service*
330 West 42nd St., N.Y.C. 36
LOngacre 4-3000

NUCLEAR CAMPUS

• AEC has made grants of $1.2-million to 15 educational institutions for equipping labs for training nuclear scientists and engineers. Largest grant, $216,950, went to Puerto Rico U. for establishment of a Spanish-language nuclear training center as part of the atoms-for-peace program (NU, Feb. '57, R12). $95,000 went to Florida U. (recent unsuccessful bidder for a reactor in the second round Power Demonstration Reactor Program) to buy an Argonaut training reactor; $80,000 went to North Carolina State to reactivate its water boiler. Penn State, Washington U. of Seattle and Washington State College were others getting six-figure grants.

• AEC also approved loan of 5,500 lb of uranium metal, in the form of Al-clad rods, to the U. S. Air Force Institute of Technology, Wright-Patterson AFB, Ohio. It will be used in a subcritical training assembly.

• The University of Chicago has endowed an Enrico Fermi Distinguished Service Professorship at its Institute of Nuclear Studies.

• 300 candidates have applied for AEC nuclear technology fellowships at the graduate level, during the '57–'58 academic year. About 150 fellows will be appointed annually. Basic stipend is $1800, with additional allowances for dependents, tuition, etc. So far 28 universities have been approved as places where the fellowship work may be carried out. For details write ORINS, P. O. Box 117, Oak Ridge, Tenn.

Courses

A five-day course on the **CURE code for reactor core design** will be conducted at the computer, at Computer Usage Co., 50 E. 42 St., New York City, May 20–24. The course is designed to assist potential users in making use of this advanced reactor code that is now available for general use. The code was programmed for KAPL by Computer Usage.

A special two-week summer program in **nuclear reactor technology** will be offered at MIT June 24 through July 5. It is intended for scientists, engineers and industrial personnel without prior professional experience in nuclear reactor technology, who wish an introduction to principles and a summary of present power reactor development status.

Aerojet-General Nucleonics' one-week **reactor training** course will be offered for the third time beginning Monday, April 22, and thereafter May 20, June 24, July 29, Aug. 26, Sept. 30, Oct. 28, and Nov. 25. The unclassified course (NU, Jan. '57, R12) covers theory, control, behavior and response of an operating AGN-201 reactor. A minimum of five and a maximum of 10 participants is required; AGN is charging $500 for the first student, $200 for each additional one from the same organization.

A **radiological physics** course leading to an M.Sc. will be offered at Columbia U. College of Physicians & Surgeons in '57–'58. A full-time course, it will include lectures, seminars, conferences and lab work. Tuition is $900.

UCLA will give graduate credit for courses in **engineering aspects of nuclear processes** and **nuclear reactor design** which it is offering at Atomics International. AI personnel are teaching the courses. Other listings are engineering fundamentals, elementary fluid mechanics, and heat transfer and thermodynamics.

A second European **atomic energy course for management** will be held Sept. 8–21 at Albert-Plage, a resort on the Belgian coast. The Societé Belge pour l'Industrie Nucléaire will be European sponsor and host; a visit to the Belgian nuclear labs at Mol will be a feature. Subsequent courses will be in Paris, where the first had been held (NU, Nov. '56, R8).

A full program of 16 graduate courses in **nuclear science and engineering** is now available at Rensselaer Polytechnic Institute, Troy, N. Y. Elementary and advanced courses lead to a "capstone" course that develops complete power reactor projects; 400 are registered for nuclear courses in the current year.

International Correspondence Schools of Scranton, Pa., has added a home course in **elements of nuclear energy,** intended for engineers, technicians, operators and maintenance men in the nuclear field.

NEWSMAKERS

John M. West, associate director of reactor engineering at Argonne and project manager of the recently dedicated EBWR, has gone to rejoin former boss **Walter H. Zinn** at General Nuclear Engineering Corp., Dunedin, Fla. He will have the title of vice president.

ACF Industries has named **Marshall G. Holloway,** former director of MIT's Lincoln Laboratory, president of its nuclear energy products division. **Rudolph Furrer,** who organized ACF's nuclear activities in 1949 and was named president of the nuclear division on its formation, will henceforth devote full time to his duties as staff vice president of manufacturing and engineering for all ACF divisions. Holloway, at Los Alamos from 1943 to 1955, helped design and build the first homogeneous reactor there, and played a leading role in atomic- and hydrogen-bomb development.

Seymour Henck, AEC public information officer at Oak Ridge 1950–55, has established Henck Associates in Atlanta, Ga., to specialize in public relations and management counseling in the nuclear field.

Robert P. Peterson, former director of nuclear research at Republic Steel, has been elected president of Applied Research, Inc., of Chicago. He will head a staff of scientists doing research and development for industry and the government in electronics, applied physics, process control and instrumentation, and applied and theoretical math.

Phillips Petroleum Co.'s atomic energy division at Idaho Falls has engaged **Robert Hickok** as project development chemist and **Eugene Vander Wall** as development chemist for new processes. Other new men include **Don Sutherland,** operations coordination engineer; **Robert S. P'Pool,** process engineering evaluator; **James Merrill,** operations evaluation statistician; **Victor Kobold,** reactor development engineer; **Myron Schellhase,** senior design engineer; and **John Alexander, Harold W. Davis, Frank J. Kelly,** and **Jack Nickerson,** reactor engineers.

Francis R. Dowling, director of Feed Materials division at Oak Ridge Operations since it was organized in July, 1954, has gone to Washington as chief of Feed Materials branch in AEC's Production division.

Atomics International has engaged **Stanley W. Mayer** and **Earl W. Murbach** as senior research chemists, and has made **M. Carl Walske** assistant chief of research under **John P. Howe.** With Los Alamos' theoretical division since 1951, Walske will be concerned with the theoretical and experimental nuclear physics research programs at Atomics International.

Thoma M. Snyder, manager of research at Knolls Atomic Power Laboratory, has been named manager of physics at General Electric's new Vallecitos Atomic Laboratory at Pleasanton, Calif.; he will be responsible for engineering, theoretical, and experimental reactor physics, mathematics, and computations.

Arthur F. Erwin has been appointed engineer in charge of a new nuclear pump section at Allis-Chalmers. He has been assistant manager of the nuclear power department at A-C since 1953. **Lynn Donelan** will be engineer in charge of design.

Walter E. Kingston, general manager of Sylvania's atomic energy division, will become executive vice president of the new Sylvania-Corning Nuclear Corp. upon its formation. Appointment of **Lee I. Davenport** as president of Sylvania-Corning was announced a month ago.

Joining General Dynamics' new Hopkins Laboratory in San Diego are **Heinz Poppendiek** of Oak Ridge National Laboratory, former chief of the heat transfer and fluid mechanics section of the nuclear aircraft propulsion program there, and **David Nicoll** of Argonne National Laboratory, who designed the control and shim rods for MTR and worked on Savannah River and EBR-2 designs. Other appointments include nuclear physicists **John R. Beyster** from Los Alamos and **Robert B. Minogue** from AEC naval reactors branch; health physicist **William Ray** of the U. S. Public Health Service Cincinnati engineering center; nuclear chemist **Rodman A. Sharp** of Brookhaven; physicist **Victor A. J. Van Lint** of the Sandia special weapons project; **Charles F. Sprague** of Los Alamos and the Office of Naval Research; and mechanical engineer **Melvin Frankel.**

Vitro Uranium Co. division of Vitro Corp. has elected **William B. Hall** presi-

ANALOG COMPUTER MODEL 3000

Simplified analog computer solves wide variety of engineering problems. Detachable problem boards and plug-in components facilitate rapid problem set-up.

Can be expanded building block fashion to larger computing system. Function generator, multiplier, chopper stabilizer, and other accessories available. Write for complete data. Model 3000, $1150, FOB Factory.
Problem board $95

DONNER SCIENTIFIC COMPANY
835 Galindo Street
Concord, California

ELLIOTT

Simulator For Training Reactor Engineers

- SIMULATES DIFFERENT TYPES OF REACTOR BY SWITCH SELECTION.
- POWER AND PERIOD TRIP SETTINGS.
- CONTROL AND INDICATION OF SHUT-OFF RODS.
- MANUAL OR AUTOMATIC CONTROL SYSTEMS.
- CHOPPER STABILISED COMPUTING AMPLIFIERS.
- LINEAR OR LOGARITHMIC RECORDING OF REACTOR POWER.

Elliott Reactor Simulator Type ND181

The Elliott range of reactor computers and simulators also includes Reactor Computer Type ND115 and Nuclear Power Station Computer Type ND111 for design studies of a reactor and nuclear power station respectively.

CONSULT ELLIOTT FOR THE INSTRUMENTATION AND CONTROL OF NUCLEAR ENERGY

ELLIOTT BROTHERS (LONDON) LIMITED, CENTURY WORKS, LONDON S.E.13 ENGLAND

D-79 GAUSSMETER

Means More In MAGNETICS . .

HERE'S WHY:

- Reads 10 to 30,000 Gauss Flux Fields
- Probe is only .025" thick
- Active area .01 square inches
- Net Weight 10-1/2 lbs.
- Power Supply 105-125 Volts, 50-60 Cycle
- Overall size 13" high, 10-1/2" wide, 6-3/4" deep

Precision built to give accurate flux density measurement and determine "flow" direction. The unit also locates and measures "stray fields," plots variations in strength, and is ideal for checking production lots against a standard. Simple to operate, the D-79 gives no ballistic reading . . . doesn't jerk or pull. Comes in protective carrying case.

Write for literature—Dept. N-457

DYNA-EMPIRE, INC.

1075 STEWART AVE
GARDEN CITY, N. Y.
Phone
Pioneer 1-2700

dent and general manager. Assistant general manager **Richard C. Cole** was elected vice president.

Another Vitro division, Vitro Laboratories, has made **R. F. Willett** new project manager at its West Orange, N. J., Laboratory.

L. M. Sharpe is president of American Nuclear Science Corp., newly formed by Nuclear Biophysics Corp. to assume most of its activities. The latter firm will continue to exist but will concentrate on biological applications of nuclear energy.

Horizons Inc., which has done much work for AEC on electrolytic reduction of metals, has elected **K. M. Bartlett** president, succeeding **Edwin T. Goodridge,** resigned.

Crane Co. has promoted **K. E. Bredtschneider** to be assistant directing engineer of nuclear and experimental engineering. He has been with the firm since 1950.

J. R. Wolff is director of research at Radiation Instrument Development Laboratory, Chicago, and will also coordinate engineering and development at R.I.D.L. and the manufacture of R.I.D.L. equipment by Intertéchnique of Versailles, France.

Richard S. Webb has been named production manager at the North Hollywood, Calif., plant of U. S. Radium.

Sydney Geltman of Johns Hopkins U. has joined the atomic and radiation physics division at the National Bureau of Standards.

Tracerlab has promoted **Abel DeHaan, Jr.,** to be director of its western division, supervising 100 engineers, scientists, and technicians in the firm's enlarged West Coast operations.

Fairchild Camera & Instrument Co. has named **C. Towner French** general manager of its industrial camera division, and **R. G. Hennessey** marketing manager and **Louis C. Prisco** sales engineering manager of its reconnaissance systems division. Fairchild's nuclear instrumentation department is a part of the latter division.

Darwin Krucoff, chief of reactor engineering in AEC's reactor development division, has been named supervisor of reactor and nuclear systems research at Armour Research Foundation, a new research section set up a month ago (NU, March '57, R12).

NUCLEAR CALENDAR

April 16–18—Symposium on nondestructive tests in the nuclear-energy field (Am. Soc. for Testing Materials jointly with ANS, AIChE, and the Society for Non-Destructive Testing), Chicago (*Morrison*). Contact W. J. McGonnagle, Argonne National Laboratory, Lemont, Ill.

April 22–26—Annual meeting American Industrial Hygiene Assn., St. Louis (*Kiel Auditorium*). Radiation sessions 25–26th. Write Rm. 1300, 28 E. Jackson Blvd., Chicago 4.

May 13–15—Annual meeting, Radiation Research Society, Rochester, N. Y. Symposia on radiation genetics and on radiation chemistry. Contact A. Edelmann, Box 10901, Pittsburgh 36.

May 14–16—Second annual Industrial Nuclear Technology conference on applied uses of radiation (Armour Research Foundation and NUCLEONICS), Chicago (Museum of Science and Industry). L. Reiffel, ARF, 3440 S. State St., Chicago.

May 28–29—Second reactive metals conference (So. California section AIME), Los Angeles (*Ambassador*). Contact B. S. Mesick, Arthur D. Little, Inc., Los Angeles.

June 6–8—Third conference on nuclear structure (Univ. Pittsburgh), Pittsburgh. Contact Norman Austern, Sarah M. Scaife Radiation Laboratory, Univ. Pittsburgh.

June 10–12—Third annual meeting, American Nuclear Society, Pittsburgh (*Wm. Penn-Sheraton*). Contact W. W. Grigorieff, exec. secy., Box 963, Oak Ridge, Tenn.

June 11–15—Third International Conference on Ionization Phenomena in Gases, Italian Physical Society, Milan. One of four sections will be on nuclear reactions in discharges, neutron production, contraction mechanisms, etc.; English is preferred language. Contact Ugo Facchini, CISE, Via Procaccini 1, Milano, Italy.

June 15–Sept. 8—International exhibition "The Atom," near Schiphol airport, Amsterdam. Ten countries including US and USSR will participate.

June 16–21—Annual meeting, Am. Soc. for Testing Materials, Atlantic City (*Chalfonte-Haddon*). Contact Fred F. Van Atta, 1916 Race St., Phila. 3, Pa.

June 17–19—Third annual meeting, Health Physics Society, Pittsburgh (*Pittsburgh U.*). Contact L. C. Emerson, ORNL, Oak Ridge, Tenn.

June 20–23—Fourth annual meeting, Society of Nuclear Medicine, Oklahoma City (*Skirvin*). Contact R. W. Lackey, 452 Metropolitan Bldg., Denver, Colo.

WASTE DISPOSAL

- RADIOACTIVE
- Explosives
- Pyrophoric Materials
- Poisonous Gases
- Flammable Materials
- Contaminated Equipment
- Toxic Materials
- Acids and Caustics

COMPLETE SEA DISPOSAL
Serving the U.S. Since 1946

CROSSROADS maintains a personal pick-up service in New England, New York, New Jersey, Ohio and Penna. for safely removing dangerous waste material.

Waste can be shipped conveniently from any outlying area with complete instructions and proper-type containers designated by CROSSROADS.

Authorized by all necessary
Federal, State and Local Authorities

•

Call, write or wire for complete information.

Crossroads

Marine Disposal Corporation
26 T Wharf, Boston, Mass.
LAfayette 3-4908

SEARCHLIGHT SECTION
(Classified Advertising)
BUSINESS OPPORTUNITIES
EQUIPMENT - USED or RESALE

UNDISPLAYED RATE
$1.50 a line. Minimum 3 lines.
DISPLAYED RATE
$15.00 per inch
ADVERTISING INCH: ½" on one column, 3 columns—30 inches—to a page.

a TERRIFIC BARGAIN in a
SOLA CONSTANT-VOLTAGE TRANSFORMER
Ends fluctuating line voltage!

BIG DISCOUNT OFF...
the factory price at a 1-input 2,000 VA unit! And here's another bonus! This Air Force 2,000 VA overstock, Sola Cat. No. 30768, has 4 inputs! 90-125 V., 190-250 V., 60 cy. or 80 cy. Isolated secondary is constant 115.0 V. ±1 % from no load to full-load of 17.4 amp. So, if you choose, use it as a 230:115 V. step-down. And slash $07.50 off the factory 1-input price! Brand new in original wood box. 4 cu.ft. Ship. wt. 254 lbs. F.O.B. Pasco, Wash. Only **$147.50**
(EXPORTERS: Note choice of 50 cycles.)
THE M. R. COMPANY
P. O. Box 1220-D Beverly Hills, Calif.

New Advertisements
received by April 10th will appear in the May issue, subject to space limitations.
Classified Advertising Division
Nucleonics
P.O. Box 12 New York 36, N. Y.

EXPORT
SALES AGENT FOR
NUCLEONIC AND ELECTRONIC
INSTRUMENTS • COMPONENTS

TRIL WORLD WIDE SERVICE

TRIL is the magic word for the fastest delivery of Nucleonic and Electronic components *the world over*. TRIL means Terminal Radio International Ltd., leading U. S. in-stock export distributor and export sales agent for America's largest manufacturers of Nucleonic and Electronic Equipment.

And, TRIL means S-P-E-E-D because TRIL delivers your order F-A-S-T-E-S-T from our own completely stocked warehouses.

VICTOREEN PRODUCTS

HI-MEG RESISTORS
Sub-Miniature Vacuum Type RX-1 (type 249)
100 megohms to 100,000,000 megohms
SUB-MINIATURE VACUUM TUBES—
COUNTER TUBES
VOLTAGE REGULATORS

MEDICAL RADIOLOGICAL INSTRUMENTS

PERSONAL AND AREA DOSIMETERS

CIVIL DEFENSE RADIOLOGICAL SURVEY METERS

SPECIAL PURPOSE AND
PHOTOMULTIPLIER TUBES

★ ★ ★ ★ ★

Your request for technical bulletins and price quotations on all your Nucleonic & Electronic requirements will receive our prompt attention.

TERMINAL RADIO INTERNATIONAL Ltd.
135 Liberty St., New York 6, N. Y.
Telephone WOrth 4-3311 • Cable: TERMRADIO

WHERE TO BUY

Rates are per inch per insertion. Contract rates are based on the use of 6 or 12 issues within the contract year, and as specified below.

1 Time	6 Times	12 Times
$21.75	20.25	18.75

EMPLOYMENT OPPORTUNITIES

NATIONAL COVERAGE

The Advertisements in this section include all employment opportunities —executive, management, technical, selling, office, skilled, manual, etc.

Positions Vacant | Civil Service Opportunities | Employment Agencies
Positions Wanted | Selling Opportunities Wanted | Employment Services
Part Time Work | Selling Opportunities Offered | Labor Bureaus

DISPLAYED —RATES— UNDISPLAYED

The advertising rate is $15.00 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.
An advertising inch is measured ⅞" vertically on a column—3 columns—30 inches to a page.
Subject to Agency Commission.

$1.50 per line, minimum 3 lines. To figure payment count 5 average words as a line.
Position Wanted ads are ½ of above rate.
Box Numbers—counts as 1 line.
Discount of 10% if full payment is made in advance for 4 consecutive insertions.
Not subject to Agency Commission.

Send NEW ADS or inquiries to Classified Adv. Div. of NUCLEONICS, P.O. Box 12, N. Y. 36, N. Y.

FILM BADGE

SALES and SERVICE

(stainless steel—weighs 1 oz.)

Beta, Gamma, Neutron and other radiation monitoring and consultation services. Provides low cost permanent records.

Prompt, reliable service.

NUCLEAR SERVICE LABORATORY
4020 Buffat Road, NE
Knoxville 14, Tennessee

RARE EARTHS

Highest purity compounds for fundamental research in physics and chemistry.

Write for information and prices of rare earth compounds.

The Gows Chemical Co., Inc.
P.O. Box 443, Laramie, Wyoming

URINALYSIS SERVICE

NSEC laboratories are staffed and equipped to perform routine and emergency urinalysis for:

- Total uranium
- Enriched uranium
- Plutonium
- Polonium
- Fission products
- Gross activities
- Other radioactive isotopes

Nuclear Science and Engineering Corp.
Subsidiary of Norden-Ketay Corporation
P.O. Box 10901, Pittsburgh 36, Penna.

Larger Sizes Now Available
HI-D® LEAD GLASS WINDOWS
For use in steel, lead, and concrete walls.
Send for Circular GS-4
PENBERTHY INSTRUMENT CO.
4301 6th AVE. SOUTH • SEATTLE 8, WASH.

REACTOR ENGINEERS AND PHYSICISTS

Are you interested in a young, growing company?

- That offers new and challenging assignments in nuclear power and special purpose reactors?
- That offers the growth opportunities of a small company in a rapidly expanding field?
- That has an attractive stock participation program, as well as other benefits.

If you are, send a brief resume of education and experience to

Internuclear Company
7 N. Brentwood Blvd.
Clayton 5, Missouri

ENGINEERS

If you have been looking for an Employment Agency that is skilled in the STATE OF THE ART of Technical Recruitment and RELIABILITY OF INFORMATION concerning positions, why not communicate with us at once! All Positions Fee Paid.

FIDELITY PERSONNEL SERVICE
1218 Chestnut St. Phila. 7, Pa.
Specialists in Aviation and Nucleonics

PROFESSIONAL SERVICES

OMEGA ENGINEERING CO.

Specialists in engineering and piping design for reactor fluid systems, structural containment, test loops, purification systems and waste disposal systems. Contact Mr. Brodsky.

70 East 45 St., N. Y. 17
Murray Hill 9-7254

REACTOR PHYSICISTS!

Here is the opportunity to work on . . .

YOUR OWN IDEAS

in a newly-formed Reactor and Nuclear System Section whose areas of interest are:

- REACTOR CONCEPTS
- REACTOR CORE CONFIGURATIONS
- REACTOR KINETICS
- SHIELDING STUDIES
- RADIATION PROCESSING CONCEPTS
- IRRADIATION FACILITY DESIGN

In addition to our programmed research, unique mechanisms exist at Armour Research Foundation permitting research on subjects of your own choosing—not just general areas—but specific problems. Complete experimental and computational facilities available including homogeneous research reactor and digital computers. For an atmosphere midway between a university laboratory and industry at industrial salary levels—with opportunity for teaching or graduate study—contact:

J. A. Metzger

ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology
10 West 35th St.
Chicago 16, Illinois

WANTED
Manufacturers' Representatives

Large manufacturer of industrial instruments is looking for technical sales representatives to handle line of instruments for the nuclear control field. Desirable territories are now available. Write to Process Instruments Sales, Section P-6-65.

Beckman / *Process Instruments*
Beckman Instruments, Inc.
Fullerton, California

INQUIRIES INVITED FROM

MATHEMATICIANS
PHYSICISTS
CHEMISTS
METALLURGISTS
CHEMICAL ENGINEERS
METALLURGICAL ENGINEERS
MECHANICAL ENGINEERS
ELECTRICAL ENGINEERS
PHYSICIANS

Argonne
NATIONAL LABORATORY

Professional Personnel Office
P. O. Box 299, Lemont, Illinois

Budd

Explorers of the Unknown in Metals—Wants High Level ENGINEERS

To Blaze New Trails in the Development & Perfection of Metals Suited for Use in

- **AIRCRAFT STRUCTURES**
- **MISSILE STRUCTURES**
- **NUCLEAR PROPULSION & REACTOR ELEMENTS**
- **NUCLEAR PROPULSION STRUCTURES**

Another *FIRST* for Budd!

Here in our Aircraft Research and Nuclear Propulsion Laboratories — an outgrowth of the research activity which produced such great industrial engineering FIRSTS as the all steel automobile body, stainless steel railway cars and the all steel two-engine planes — BUDD has just reached another milestone in its exploratory achievements: a solution to the practical and efficient manufacture of structures for aircraft and missiles subject to aerodynamic heating has been found!

With a manufacturing background of nearly half a century and more than 20,000 people on its payroll, The BUDD Company is the established leader in its field. To competent Technical and Scientific Personnel seeking an association with a company offering established employment stability and salaries commensurate with ability, there *truly* is no finer place to work.

If you are interested in an association in a high level research environment, in one of our plants in the East, please fill in the Ready-Reference Card below and send to THE PLANT OF YOUR CHOICE, today, along with a complete resume of your educational and work background.

Mail Today!

READY-REFERENCE CARD

ENGINEERING EMPLOYMENT SERVICE

Address Your Inquiry To One Of The Following:

THE BUDD COMPANY

Personnel Manager
HUNTING PARK PLANT
Philadelphia 32, Pa.

Personnel Manager
RED LION PLANT
Bustleton, Pa.

Personnel Manager
CHARLEVOIX PLANT
Detroit 15, Michigan

Personnel Manager
CHASE PLANT
Gary, Indiana

NAME _____ Date _____
(Last) (First) (Middle)

PRESENT ADDRESS _____

BIRTH DATE _____ ARE YOU A CITIZEN OF U.S.? YES ___ NO ___ DATE AVAILABLE _____

List in order of preference positions for which you feel best qualified:
1 _____ 2 _____ 3 _____

EDUCATION	NAMES & LOCATIONS	DATES ATTENDED	COURSE	DEGREE	DATE
High School					
College					
Other					

NAME OF PRESENT OR MOST RECENT EMPLOYER _____

ADDRESS _____ CITY AND STATE _____

POSITION HELD _____ EARNINGS _____

(THIS INFORMATION WILL BE HELD IN STRICT AND COMPLETE CONFIDENCE)

Is Your Resume Attached?

ENGINEERS AND PHYSICISTS

Work-Study Plan for
Master's Degree in Chosen Field

sponsored by

Knolls Atomic Power Laboratory

in conjunction with

Rensselaer Polytechnic Institute

CANDIDATES BEING CHOSEN NOW FOR COURSES BEGINNING IN JUNE AND SEPTEMBER

Knolls, operated by General Electric for the Atomic Energy Commission, is developing a two-reactor system for the new Triton, the world's largest submarine; another new project... to design a reactor for a Navy destroyer power plant system. Qualified young engineers and physicists who join the new WORK-STUDY PLAN can start immediately on some phase of these large-scale programs.

The Plan pays approximately 85% of full salary the first year and 100% the next. The Master's degree can be obtained in 2½ years or less, depending on individual background. The candidate takes his M.S. in the field of his choice, with a minor in nuclear engineering.

If you have a B.S. degree in engineering or physics, you are eligible to apply.

1st SEMESTER:	*Half time at R.P.I.—fees and tuition paid; half time on job, half pay.*
2nd SEMESTER:	*Half time on job, half time off for special nuclear courses at laboratory; full pay; fees and tuition paid.*
SUCCEEDING TERMS:	*Full time on job—full pay; up to 4 hours off each week to attend classes at R.P.I. Full tuition refund.*

MEMO TO ENGINEERS AND SCIENTISTS AT ALL LEVELS:

Your inquiries are also invited for a number of attractive positions now open—outside of Work-Study Plan.

If you are interested in this program, send a resume of your education and experience to:

Mr. A. J. Scipione, Dept. 460

Knolls Atomic Power Laboratory

OPERATED FOR A.E.C. BY

GENERAL ELECTRIC

SCHENECTADY, N. Y.

ENGINEERS AND SCIENTISTS

with degrees in
E.E., M.E., Ch.E., or PHYSICS

Honeywell
BROWN INSTRUMENTS

First in Controls

LEADS THE WAY IN A WORLD OF OPPORTUNITIES

- THE COMPANY—Judging a company on its past performance constitutes sound logical thinking. Looking over BROWN INSTRUMENTS record of accomplishment tells a reassuring story of continuous growth during nearly a century of pioneering in the industrial instruments and control field.
- ASSIGNMENTS — Diversified . . . permanent, non-routine, in the newest scientific field of NUCLEAR INSTRUMENTATION and AUTOMATION. The bulk of our work is for industrial use.
- COMPENSATION—Rewarding . . . salaries are competitive with those offered in other industries. Our benefits include free group health insurance, hospitalization and surgical benefits, as well as an excellent retirement plan. Relocation assistance.
- GROWTH — Unlimited . . . your performance and salary is re-evaluated twice yearly. Our policy to promote from within is responsible for present management.
- EDUCATION—Excellent . . . financial assistance for those desirous of furthering their education at one of several renowned Philadelphia colleges or universities.
- Men with the vision to create and the will to act can find an abundant outlet for their creative talent in either RESEARCH, DESIGN and DEVELOPMENT APPLICATION, or SYSTEMS ENGINEERING. Whatever the choice, you and only you will be able to control and measure your progress with this company, which leads the way in a world of opportunities . . .

Write to D. R. GARVEY
Manager Employment, Dept. N

Honeywell
BROWN INSTRUMENTS DIV.
Wayne & Windrim Aves.
Philadelphia 44, Pa.

ENGINEERING PHYSICIST

TO EVALUATE
REACTOR FUEL
RESEARCH

for Advanced
Engineering Component of

HANFORD ATOMIC PRODUCTS OPERATION

New Fuels Preparation Dept.

Ability to provide consultation and advice on long-range business implications of physics development is as essential in this position as ability to analyze and evaluate research and development programs supporting reactor fuel development.

An engineering physicist with this dual ability who joins the new Fuels Preparation Department now will be strategically placed to assume increasing responsibility in the Hanford operation, whose scope is being broadened by important advances in atomic research.

Requirements: B.S. or B.A. in Physics, plus 10 or more years' experience in Engineering Physics and at least 5 in Neutronics. (An advanced degree may be offered in lieu of experience.)

Men with these qualifications are invited to submit their resume, in complete confidence to Mr. E. P. Galbraith, Manager, Technical Personnel Placement.

DEPT. FPO
Hanford Atomic Products Operation

GENERAL ELECTRIC

Richland, Washington

GENERAL PHYSICS LABORATORY DIRECTOR

The new central research laboratory of Continental Can Company has an exceptional opportunity for a versatile physicist to direct a long range research group in the application of acoustics, optics, mathematical physics, and other fundamental fields to a wide variety of problems in such areas as energy conversion, automatic control, instrumentation and communications. Administrative duties will be minimized in order to allow continued professional development of staff members, and opportunities for close cooperation with scientists in chemistry, metallurgy, and biology will be found. Facilities and equipment are believed to be second to none in variety and extent. Please write, giving a brief resume of qualifications, to Director, Physics Research, Central Research & Engineering Division, 7622 South Racine Avenue, Chicago 20, Illinois

SENIOR NUCLEAR ENGINEERS THEORETICAL NUCLEAR PHYSICISTS

Assignment in our Reactor Engineering Department on the San Francisco peninsula of California.

Please mail complete chronological experience record.

AMERICAN-STANDARD
Atomic Energy Division
1682 Broadway
Redwood City, California

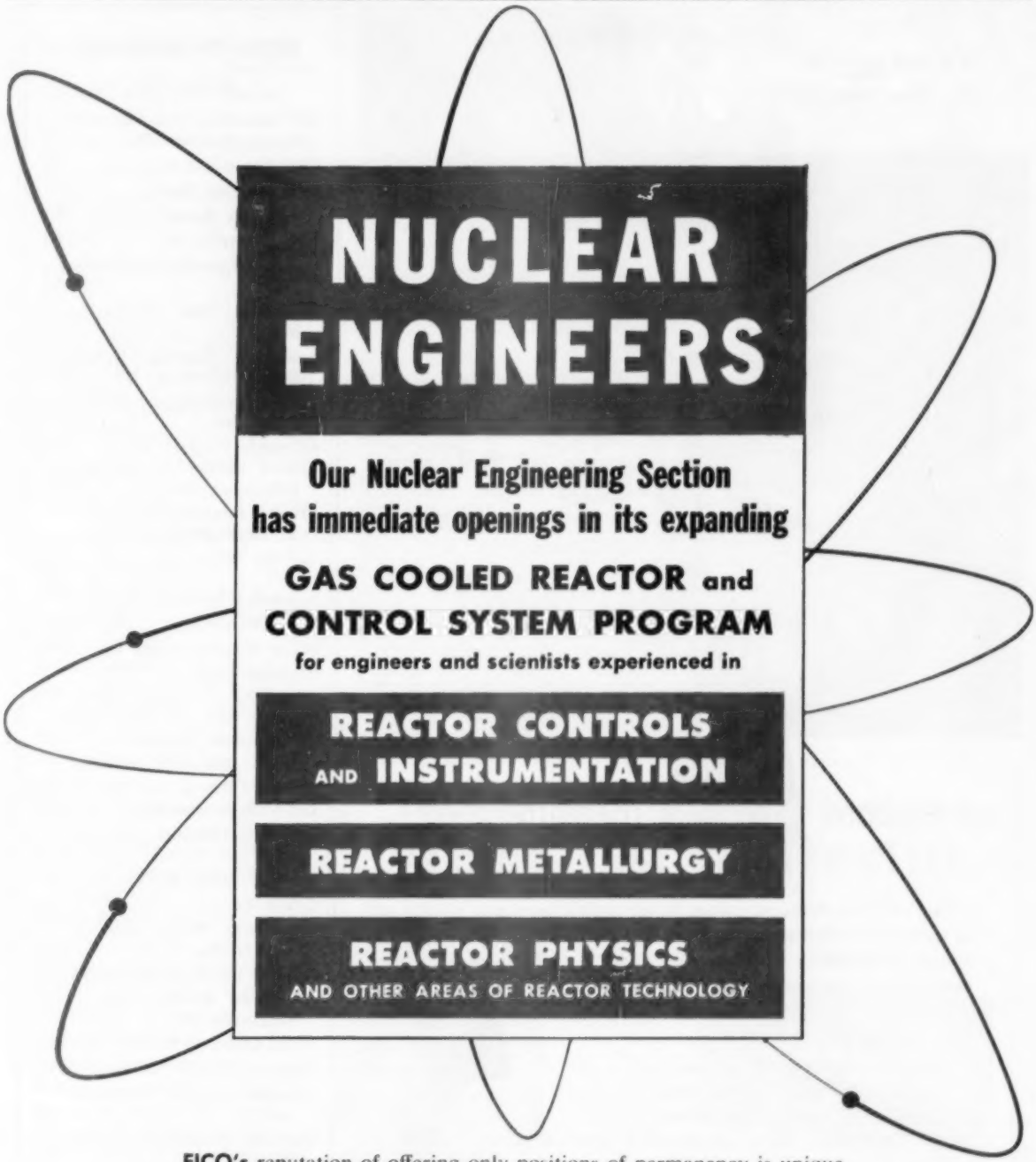
2 PHYSICISTS—$9600—$11,500
NO FEE
2 young men who are looking for a positive future will have an open door for advancement with this leading midwest concern. Some experience in solid state physics is necessary.
Reply in strict confidence to—
F. CARTER
6 N. Michigan — Room 708
Chicago, Ill. — FInancial 6-1155

QUICK SOLUTION TO MAN POWER PROBLEMS . . .

through the EMPLOYMENT OPPORTUNITIES Section of the publication. The market place for those offering or wanting the services of men on engineering, technical and executive level.

This section offers a quick, effective solution to your man power problems, because its readership is confined to just the type of men you need . . . Waste circulation is avoided . . . You reach only the men you want.

NUCLEONICS
P.O. Box 12
Classified Adv. Div., New York 36, N. Y.



NUCLEAR ENGINEERS

Our Nuclear Engineering Section has immediate openings in its expanding

GAS COOLED REACTOR and CONTROL SYSTEM PROGRAM

for engineers and scientists experienced in

REACTOR CONTROLS AND INSTRUMENTATION

REACTOR METALLURGY

REACTOR PHYSICS
AND OTHER AREAS OF REACTOR TECHNOLOGY

FICO's reputation of offering only positions of permanency is unique.
We employ only when there is a clear and definite need projected years into the future.
Send for a copy of "— and It's a Good Place to Work,"
a brochure yours for the asking.

Phone (New York) STillwell 4-9000 or write to Philip McCaffrey

FORD INSTRUMENT CO.

DIVISION OF SPERRY RAND CORPORATION
31-10 THOMSON AVE. • LONG ISLAND CITY 1, N. Y.

It's just part of the Victoreen story...

Interchangeable probes offer total dose measurements from 1.6 mr to 499,500 r; delivery rates from 0.018 to 50,000 r/min.

continuous RADIATION measurement

The Victoreen Radocon enables the physicist or technician to control radiation rate and total amount of radiation reliably ... accurately ... continuously — and *completely automatically.* There's no trial calculation, no error ... no taking readings and recharging.

Pre-established amount of radiation is set on counter dials and intensity range selected. Ionization probe is then placed in radiation field. Upon completion, a buzzer sounds and a relay activates a mechanism to switch off the source or block the beam — *automatically.*

No matter what standards of comparison you use — reliability, accuracy, flexibility — think of Victoreen *first.* That's *Victoreen, the name that means radiation measurement, protection and control.*

AA-5004

Get the full story on the Radocon. A letter, card or call will bring your free copy of Form 3043.

The Victoreen Instrument Company
Instruments Division
5806 Hough Avenue, Cleveland 3, Ohio

INDEX TO ADVERTISERS

APRIL, 1957

ACF Industries Inc., Nuclear Energy Products Div. 49
AMF Atomics Inc. 56
Adlers Metal Works 100
Advertising Council 8D
Alco Products Inc. 113
American Laundry Machinery Co. 94
American Time Products, Inc. 11
American Tradair Corp., Ekco Electronics, Ltd. . . . 119
Anton Electronics Laboratories, Inc. 125
Assembly Products Inc. 101
Atomic Energy of Canada Ltd. 31
Atomics International a Div. of North American Aviation, Inc. 52, 112, 122, 126, 130
Babcock & Wilcox Company . 4, 5
Baird-Atomic Inc. . . . . 3rd Cover
Barco Manufacturing Co. . . 131
Blickman Inc., S. 3
Carborundum Metals Company, Div. of The Carborundum Company 39
Central Research Laboratories, Inc. 35
Cohn Corp. Sigmund 119
Columbia-National Corporation 7
Corning Glass Works 91
Crane Co. 46
Crossroads Marine Disposal Corporation 135
Davison Chemical Company . 143
Daystrom Nuclear, Div. of Daystrom Inc. 51
Delta Chemical Works, Inc. . 108
Donner Scientific Company . 133
Douglas Aircraft Company, Inc. 8
DuMont Laboratories, Inc., Allen B. 45
Dyna-Empire, Inc. 134
Elliott Brothers, Ltd. 134
Fansteel Metallurgical Corp. 97
Fenn Manufacturing Company 95
Ford Instrument Co., Div. of Sperry Rand Corporation 14
Foster Wheeler Corporation 9
Gaertner Scientific Corp. . . 114
General Dynamics Corp., Electric Boat Division . . . 6

General Electric Company 2nd Cover
General Mills Mechanical Div. 110
General Transistor Corp. 43
Gows Chemical Co., Inc. .. 136
Health Physics Services, Inc. . 101
International Nickel Company 47
Isotope Developments Limited 110
Kewaunee Mfg. Co. 101
Kinney Mfg. Division, The New York Air Brake Company 103
Kollmorgen Optical Corp. .. 102
Leeds & Northrup 38
Lindsay Chemical Company . 109
Los Alamos Scientific Laboratory 57
Mallory & Co., Inc. P. R. 8A
Martin Company, The . . 48, 99
McGraw-Hill Book Co. 94
McGraw-Hill Technical Writing Service 132
McKay Company, Inc. David 118
Metals & Controls Corporation Nuclear Products Division 93
Mettler Instrument Corp. 50
Minneapolis-Honeywell Regulator Co., Industrial Division ..... 4th Cover
National Carbon Co. a Division of Union Carbide & Carbon Corp. 30
National Lead Company ... 40
Norton Company 33
Nuclear-Chicago Corp. . . 8B, 8C
Nuclear Development Corporation of America 16
Nuclear-Electronics Corp. . . 116
Nuclear Enterprises Ltd. 92
Nuclear Measurements Corp. 126
Nuclear Science & Engineering Corp., Subs. of Norden-Ketay Corp. 136
Nuclear Service Laboratory . 136
Nuclear Systems a Div. of the Budd Company 60
Nucleonics 54, 55
Pacific Coast Engineering Co. 75
Penberthy Instrument Co. . . 136
Picker X-Ray Corporation . . 124
Potter Aeronautical Corporation 96
Radiation Counter Laboratories Inc. 29
Radiation Instrument Co. . . 108

Ready to Serve

. . . those industries and companies which have set their sights on the profitable possibilities in the nuclear chemistry field, the Davison Chemical Co. has consolidated its operations in THORIUM AND RARE EARTHS CHEMICALS.

Two plants, one at Pompton Plains, N. J. (formerly Rare Earths, Inc.) and one at Baltimore, Md. are in operation. Your inquiries concerning our products and services are welcomed.

DAVISON CHEMICAL COMPANY

Division of W. R. Grace & Co.

Baltimore 3, Md. and Box 488 Pompton Plains, N. J.

TULLAMORE announces the Model VTE-1

VACUUM TUBE ELECTROMETER

The VTE—1 is a practical instrument for the modern nuclear physics laboratory. Small currents may be measured accurately and reliably. A bucking current supply enables the operator to measure extremely small current variations.

SPECIFICATIONS:

1. Current Range—10^{-3} to 10^{-11} amps.
2. Bucking Current Range—10^{-3} to 10^{-9} amps.
3. Time Constants—0.1, 0.3, 1, 3, 10, and 30 seconds.
4. Drift—less than $\frac{1}{2}$% per day after $\frac{1}{2}$ hour warmup.
5. Trip Circuits—Hi and Lo level trip circuits may be included for reactor control applications.

—RELIABLE—
—INEXPENSIVE—
—PRECISE—

IDEALLY SUITED FOR THE MEASUREMENT OF CURRENTS FROM SCINTILLATION COUNTERS AND IONIZATION CHAMBERS

Address inquiries to:

TULLAMORE
ELECTRONIC LABORATORY
6055 South Ashland Ave. • Chicago 36, Illinois

MODEL 212
"Ultra Stable"
HIGH VOLTAGE SUPPLY

$$\Delta E_0 = (20 + 0.25E_v)\frac{E_{ac}}{30} - 0.1E_0\Delta T^*$$

- *500 to 1800 Volts* continuously variable in 17 steps with a ten turn Helipot covering any step.
- *85A2 Reference Tubes* with their inherent long term stability are shielded to reduce short term temperature fluctuations.
- *2 MV Regulation at 1800 DC per volt change of line* over the range of 95 to 125V.
- *Positive, Negative or Zero* output, selected from panel.
- *5 ma — 2 ohm* output characteristic over entire range with rapid recovery from load transients.
- *Hermetically Sealed* high voltage transformer.
- *2000:1 Precision Volt Box* for calibration with an inherent stability of 0.005%.

* E_o = output in volts
E_v = vernier setting in volts
ΔE_0 = change in mv
ΔT = ambient temperature change in °C
E_{ac} = line voltage change

Delivery from stock

RIDL RADIATION INSTRUMENT DEVELOPMENT LABORATORY
5737 South Halsted • Chicago 21, Illinois
Telephone WEntworth 6-2346 • Cable Address RADILAB

Radiation Instrument Development Laboratory . . . 144
Resistoflex Corporation 117
Robertshaw-Fulton Controls Co. 53
Rocketdyne A Division of North American Aviation, Inc. 106
Ross Heat Exchanger Division of American-Standard 34
Sandia Corporation 118
Sargent & Lundy Engineers 41
Searchlight Section . . . 135–141
Societe D'Applications Industrielles de la Physique . 129
Solar Aircraft Company . . . 12
Struthers Wells Corporation . 15
Superior Tube Company . . . 107
Sylvania Electric Products, Inc. 36
Technical Associates 127
Technical Operations, Inc. 100, 108
Terminal Radio International Ltd. 135
Thermal American Fused Quartz Co. 98
Thermo Electric Co., Inc. . . . 129
Traceriab 44
Tullamore Electronic Laboratory 143
U.S. Industrial Chemicals Co. 10, 121
U.S. Stoneware 13
University of California Radiation Laboratory . . . 42
Victoreen Instrument Company 142
Westinghouse Bettis Plant . . 37
Where to Buy 136
White Industrial Division S. S. 111
Zallea Brothers 32

PROFESSIONAL SERVICES 136
CLASSIFIED ADVERTISING
F. J. Eberle, Business Mgr.
EMPLOYMENT OPPORTUNITIES 136–141
EQUIPMENT
(Used or Surplus New)
For Sale 135
American-Standard Atomic Energy Div. 140
Argonne National Laboratory 137
Armour Research Foundation of Ill. Inst. of Tech. 136
Beckman Instruments Inc. 136
Budd Co., The 138
Carter, F. 140
Continental Can Co., Inc. 140
Fidelity Personnel Service 136
Ford Instrument Co. Div. of Sperry Rand Corp. 141
General Electric Co. 139, 140
Honeywell Brown Instruments Division. 140
Internuclear Co. 136
M. R. Co., The 135

This index is published as a service. Every care is taken to make it accurate, but NUCLEONICS assumes no responsibility for errors or omissions.

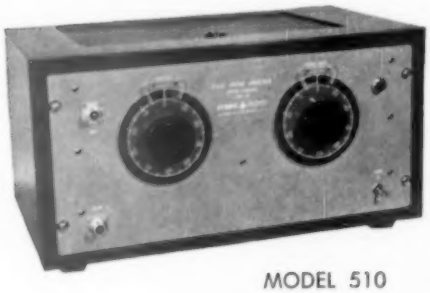
BAIRD ATOMIC

DIFFERENTIAL PULSE HEIGHT ANALYZERS

MODEL 520

MULTI-CHANNEL

- Twenty fixed adjacent channels (0.5 volt each) may be moved as a group over a 60 volt spectrum, dividing the spectrum into 120 parts.
- Many units in use in leading university and atomic energy laboratories over last few years with outstanding performance.
- Simultaneous pulse height measurements reduce operating time of expensive equipment used to produce data.
- Saves man hours of skilled scientific personnel.
- Rapid taking of isotope spectrum data eliminates decay corrections.
- A completely detailed professionally prepared instruction manual (over 100 pages) furnished with each instrument.



MODEL 510

SINGLE CHANNEL

- Hundreds of these units in use over the last 5 years have established the Model 510 Analyzer as the standard in radioisotope laboratories.
- Used for studies of energy distribution of nuclear particles. Permits separate counting of isotopes in mixtures. Reduces background count to permit counting of low concentration or low energy isotopes.
- Furnished with final instruction book.

The Model 510 allows only those pulses falling between two set amplitudes to pass through to the output to be counted or recorded. Pulses above and below selected levels are rejected. Full range, 0-100 volts, channel width, 0-7 volts — both controlled by helical potentiometers.

Negative output variable to —15 volts. Model 510 may be used as an integral discriminator by setting channel width at 10 volts.

Plan to visit Booth 115 at the 1957 Convention of the Federation of American Societies for Experimental Biology — Conrad Hilton Hotel, Chicago, April 15-19.

SALES REPRESENTATIVES

- ATOMIC ASSOCIATES, INC. — New York, Boston, Philadelphia
- W. A. BROWN & ASSOCIATES, INC. — Alexandria, Va.
- H. E. RANSFORD CO. — Pittsburgh
- PACKARD INSTRUMENT CO. — LaGrange, Ill.
- CANADIAN MARCONI CO. — Montreal, Toronto, Winnipeg, Vancouver, Halifax

- OVERSEAS

Australia, Belgium, Denmark, France, India, Israel, Italy, Japan, Norway, Mexico, Sweden, Switzerland

BAIRD ATOMIC

Baird-Atomic, Inc.

33 UNIVERSITY ROAD, CAMBRIDGE 38, MASS.

From one source

ALCO Products, Inc. technicians check operation of Army Package Power Reactor on a Honeywell control panel at ALCO's criticality facility in Schenectady, N.Y.

. . . reactor instrumentation for every need

As soon as you start planning controls for your nuclear reactor, consider the advantages of having Honeywell design, engineer, assemble, test and service your instrumentation for you.

Honeywell can supply all the instrumentation you need—a single amplifier, thermocouple or recorder, or a complete custom-made, packaged system.

From this one reliable source comes first-quality instruments, designs that have been proved in practice since the very inception of the atomic energy program, specialized engineering assistance . . . and undivided responsibility for your installation. From the industry's largest-by-far service organization, you get all the help you need with installation, startup and maintenance of your controls.

When your plans begin to take shape, contact your nearby Honeywell sales engineer for assistance. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls